Chapter Four—Nonstructural and Small-Scale Upland Management

4.1 Introduction

Traditionally, stormwater has been managed using large, structural practices installed at the low end of development sites--essentially as an afterthought--on land segments leftover after subdividing property. This approach, sometimes referred to as end-of-pipe management, yields the apparent advantages of centralizing control and limiting expenditure of land. Unfortunately, it is much less efficient than it appears. In the last decade, alternative approaches have been established that employ nonstructural and upland practices with results that far surpass the end-of-pipe approach.

Use of nonstructural and upland practices does not supplant use of end-of-pipe technology. Hybrid approaches, which incorporate both types of practice, work quite effectively. However, as nonstructural and upland practices tend to reduce adverse environmental impact, Rhode Island regulatory agencies will typically expect permittees to exhaust all opportunities to use such practices prior to exploring end-of-pipe management. Developers should consider nonstructural and upland technologies as first-line practices and are required to recharge stormwater in accordance with the groundwater recharge requirement (refer to chapter 7).

This section of the *Rhode Island Stormwater Manual* focuses on the proper use of nonstructural and upland practices for the State of Rhode Island. It draws primarily from the methodologies referred to as "better site design" and "low-impact development," which have been established by the Center for Watershed Protection and Prince George's County, Maryland, respectively. These methods are considered critical to proper stormwater management and should be incorporated into all projects. This section discusses:

- Advantages of nonstructural and upland management.
- Four fundamental concepts that frame the application of nonstructural and upland management.
- Appropriate use of a variety of nonstructural and upland management practices.

4.1.1 Advantages of Nonstructural and Upland Management

Nonstructural and upland management refers to the use of small management practices that require minimal hard construction and feature installations that are strategically located throughout a development to work with predevelopment hydrologic conditions. Nonstructural and upland practices generally provide the following advantages over the end-of-pipe approach:

- *Reduced consumption of land for stormwater management.* Nonstructural and upland practices engage the natural capacity of undisturbed land to absorb precipitation thus reducing the need for structural controls. When structural controls are used, they are small, close to the source of runoff, often installed below grade and made to fit well into the general landscape. Little land is expended for stormwater management.

- *Reduced construction costs.* Traditional stormwater management requires significant sewering and earthwork. Nonstructural and upland methods apply controls as close to sources of runoff as possible. Wherever practicable, conveyances incorporate natural flow paths and swales instead of pipes. Structures installed are small, thus reducing the need for excavation and construction materials.
- *Ease of maintenance.* Nonstructural and upland practices require limited maintenance. Much of the maintenance that is required can be accomplished by the average landowner.
- *Reduced impacts from failure.* If an end-of-pipe practice fails, an entire catchment may be affected. If a nonstructural or distributed practice fails, the extent of impact is localized to a much smaller area. Moreover, nonstructural and upland practices incorporate simpler devices that are less likely to malfunction.
- *Takes advantage of site hydrology.* Nonstructural and upland management mimics natural site hydrology and exploits the tendency of undisturbed land to retain and absorb runoff from impervious surface. Runoff that is absorbed recharges groundwater and stream baseflow and does not need to be managed or controlled by an end-of-pipe practice. Reduced end-of-pipe discharge is also better for streambank stability and habitat.
- *Better quality of discharge.* Recent research indicates that most constructed technologies are unable reduce pollutant concentrations below certain thresholds, which may exceed water quality standards. Landscapes that utilize nonstructural and upland practices minimize discharge and often retain all runoff from events smaller than the 2-year, 24-hour storm. Pollution is minimized because discharge is minimized.
- *More aesthetically pleasing development.* Traditional stormwater management tends to incorporate the use of large, unnatural looking practices such as detention ponds. When neglected, these practices may present drowning and mosquito breeding hazards. Nonstructural and upland practices utilize predevelopment land features that are small and fit well into the natural landscape.
- *Improved profit margin.* The advantages of nonstructural and upland management translate into the marketplace. The value added is significant. Several studies indicate that the cost of applying these nonstructural and upland stormwater management techniques is about half that of the traditional approach. The results of one example of such a study are summarized in Table 4.1-1 below (Schueler, 2000). Properties developed using nonstructural and upland stormwater practices tend to command higher sale prices.

Table 4.1-1
Cost Analysis for Convention and Alternative Development

Cost Categories	Conventional Development	Alternative Development[a]
Engineering	$79,600	$39,800

Road Construction	(20,250 linear ft.) $1,012,500	(9,750 linear ft.) $487,500
Sewer and Water	$25,200	$13,200
Other Costs	$111,730	$54,050
Total	$1,229,030	$594,550

Table Notes
Source: Center for Watershed Protection, 2000, The Practice of Watershed Protection, page 175.
[a]Alternative development cost analysis was done for cluster development, which is similar to conservation development.

4.1.2 Integrating with Alternative Development

Nonstructural and upland practices integrate well with alternative development approaches such as conservation design, open-space design and creative design. There are many manuals available on these techniques. Recently, the concept of rural development has been described in the *South County Design Manual* (Flinker, 2001) and *The Rhode Island Conservation Development Manual* (Flinker and Millar, 2003), which were published by the Rhode Island Department of Environmental Management (RIDEM), *Urban Design Manual* (RIDEM, in press) and the *Rural Design Manual* (RIDEM, 1998). A discussion of appropriate zoning policies to implement these approaches is discussed in the *Scituate Reservoir Watershed Zoning Project* (RIDEM, 1998). Please refer to these manuals for more information on this topic.

4.2 Fundamental concepts

Management at end of pipe focuses on the application of technology to reduce pollutant loads in a waste stream. By contrast, nonstructural and upland management is a process of evaluating options for site development that prevent the creation of a stormwater waste stream. It requires careful consideration of how one can most effectively work with the predevelopment layout of a given site. In considering the advantages and constraints of each site, four fundamental concepts should remain preeminent:

- Minimizing site disturbance.
- Working with site hydrology.
- Minimizing and disconnecting impervious surface.
- Applying small-scale controls at the source.

These concepts are summarized in sections 4.2.1-4.2.4. Management practices applicable to each of these four concepts are detailed in section 4.3.

4.2.1 Minimizing site disturbance

Undisturbed lands possess a natural capacity to store stormwater runoff. Development sites may include areas that are relatively sensitive to impact from construction (e.g., erosion) or may encompass particularly rare or valuable environmental features. Protecting susceptible natural features provides the multiple benefits of preserving important resources, reducing development impact and providing capacity for the attenuation of stormwater.

Generally, developers should inventory and map natural features such as surface waters, vegetated wetlands, woodlands and highly erodible soils, for preservation early in the site planning process. This helps to define a practicable development envelope. Preserved areas must be protected throughout construction and demarcated for conservation in land records. Where appropriate undisturbed areas may also serve as small-scale stormwater controls.

4.2.2 Working with site hydrology

Traditional stormwater management seeks to eliminate the annoyance and hazard of runoff by rapidly conveying it away from development—typically, via closed drainage systems such as storm sewers. This approach works efficiently to remove water from streets and sidewalks, but it expends significant capital for constructed systems that interrupt the recharge of groundwater resources. By contrast, nonstructural and small-scale upland management techniques work to reduce stormwater generation or retain it in the upland where it can percolate naturally into the soil and replenish groundwater resources.

4.2.3 Minimizing and disconnecting impervious surface

Runoff comes primarily from impervious surface, such rooftops, roadways or any smooth hard surface that prevents water from absorbing into the ground. Traditional developments tend to include superfluous impervious surface, which may minimized with thoughtful site planning. Techniques to limit impervious area include reducing road widths and lengths as well as the area of rooftops (e.g., preference for two-story over single-story buildings).

To the extent possible, developers should promote contact between runoff and pervious land surface. Technically, this is done by increasing time of concentration—length of time required for runoff to concentrate and flow off site—and by reducing curve number--a representation of the portion of stormwater that is not retained on the ground surface and therefore, available to runoff. (An in-depth discussion of "time of concentration" and "curve number" is contained in Technical Review-55 (SCS, 1986).) Using practices that work with site hydrology, nonstructural and small-scale upland practices can often control the entire water quality volume from a development site.

4.2.4 Applying small-scale controls at the source

Small-scale practices applied at the source—or as close as practicable—can offer significant advantages over conventional, engineered facilities such as ponds or concrete conveyances. They can decrease the use of typical engineering materials such as steel and concrete. By using materials such as native plants, soil and gravel these systems can be more easily integrated into the landscape and appear to be much more natural than engineered systems. The natural characteristics may also increase homeowner acceptance and willingness to adopt and maintain such systems. Small, distributed systems also offer a major technical advantage—one or more of the systems can fail without undermining the overall integrity of the site control strategy.

Small-scale practices reduce safety concerns as they feature shallow basin depths and gentle side slopes. The integration of these facilities into the landscape throughout the site offers more opportunities to mimic the natural hydrologic functions and add aesthetic value. The adoption of these landscape features by the general public and individual property owners can result in significant maintenance and upkeep savings to the homeowners association, municipality or other management entity.

4.3 Applying Nonstructural Techniques and Upland Controls

The stormwater practices and techniques covered in this section of the *Rhode Island Stormwater Manual* are grouped to support the four fundamental concepts discussed in the previous section and are listed below:

Minimizing Site Disturbance
- Limits of Clearing and Grading.
- Preserving Natural Areas.
- Avoid Disturbing Long, Steep Slopes.
- Minimize Siting on Porous and Erodible Soils.

Working with Site Hydrology

Minimizing and Disconnecting Impervious Surface
- Roadways.
- Buildings.
- Parking Footprints.
- Parking Lot Islands.
- Disconnecting Impervious Area.

Applying Small-Scale Controls at the Source
- Vegetated Filter Strips.
- Natural Drainage Ways.
- Green Roofs and Facades.
- Rain Barrels and Cisterns.
- Dry Wells.

4.3.1 Minimizing Site Disturbance

4.3.1.1 Limits of Clearing and Grading

Perhaps the most potentially destructive stage in land development is the preparation of a site for building--clearing of vegetation and soil grading (Schueler, 1995). The limits of clearing and grading refer to the part of the site where development will occur. This includes all impervious areas such as roads, sidewalks, rooftops, as well as areas such as lawn and open drainage systems.

To minimize impacts, the area of development should be located in the least sensitive areas available. At a minimum, developers should avoid streams, floodplains, wetlands, and steep slopes (see sections 4.3.1.3). Where practicable, developers should also avoid soils with high infiltration rates as these will aid in reducing runoff volumes (see section 4.3.1.4).

Advantages

- Preserves more undisturbed natural areas on a development site.
- Techniques can be used to help protect natural conservation areas and other site features.
- Promotes evapotranspiration and infiltration to reduce need for treatment and peak volume control at end-of-pipe.
- Reduces generation of stormwater.
- Helps to demonstrate compliance with regulatory standards (e.g., freshwater wetlands, coastal resources, water quality, wildlife, local environmental protection, etc.) for avoidance and minimization as well as setbacks from sensitive features.
- Maintains predevelopment hydrology, natural character and aesthetic features that may increase market value.
- Promotes stable soils.
- May reduce landscaping costs.

Use

Establishing a limit of disturbance based on maximum disturbance zone radii/lengths. These maximum distances should reflect reasonable construction techniques and

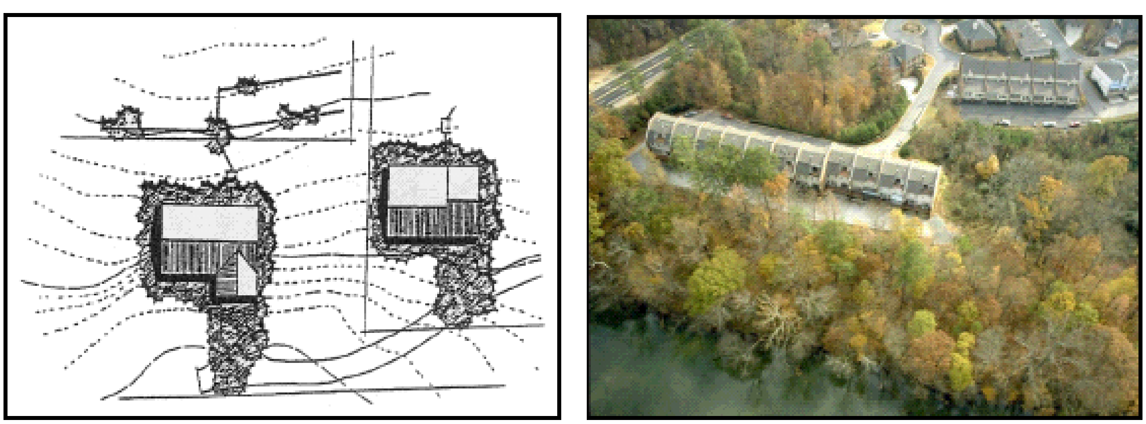


Figure 4.3.1.1-a Reduced limits of disturbance minimize water quality impacts. Source: Adapted from Atlanta Regional Commission, 2001.

equipment needs together with the physical situation of the development site such as slopes or soils. Limits of disturbance may vary by type of development, size of lot or site, and by the specific development feature involved.

Standards

Generally speaking, limits of disturbance need not comprise more than:

a) Area of the building pad plus 15 feet.

b) Area of a roadbed and shoulder plus 5 feet.

(This is not intended to limit lawn areas.)

4.3.1.2 Preserving Natural Areas

Natural areas include woodlands, riparian corridors, areas contiguous to wetlands and other hydrologically sensitive and naturally vegetated areas. To the extent practicable these areas should be preserved.

Natural areas can be one of the most important components within a development scheme, not only from a stormwater management perspective, but in reducing noise pollution and providing valuable wildlife habitat and scenic values. New development tends to fragment large tracts of undisturbed areas and displace plant and animal species; therefore it is essential to maintain these buffers in order to minimize impacts. Areas adjacent to waterbodies (both freshwater and coastal) are protected under Rhode Island state law and cannot be altered without a state agency (DEM or CRMC) permit.

Advantages

- Promotes evapotranspiration and infiltration to reduce need for treatment and peak volume control at end-of-pipe (see "Buffers and Undisturbed Areas" in *General Use, Small-Scale Controls in the Upland*).
- Reduces generation of stormwater.
- Helps to demonstrate compliance with regulatory standards (e.g., freshwater wetlands, coastal resources, water quality, wildlife, local environmental protection, etc.) for avoidance and minimization as well as setbacks from sensitive features.
- Reduces safety and property-damage risks where flood hazard areas are incorporated into preservation.
- Maintains predevelopment hydrology, natural character and aesthetic features that may increase market value.
- Promotes stable soils.
- Establishes and maintains open space corridors.

Use

a) Check all federal, state and local enforceable policy to ensure proper setbacks and identification of preservation areas. Identify areas for preservation through site analysis using maps and aerial or satellite photography or by conducting a site visit.
b) Delineate areas for preservation via limits of disturbance before any clearing or construction begins and should be used to set the development envelope as well as guide site layout. Clearly mark areas for preservation on all construction and grading plans to ensure that equipment is kept out of these areas and that native vegetation is kept in an undisturbed state.
c) Protect preservation areas in perpetuity by legally enforceable deed restrictions, conservation easements and maintenance agreements.

Figure 4.3.1.2-a shows a site map with undisturbed natural areas delineated.

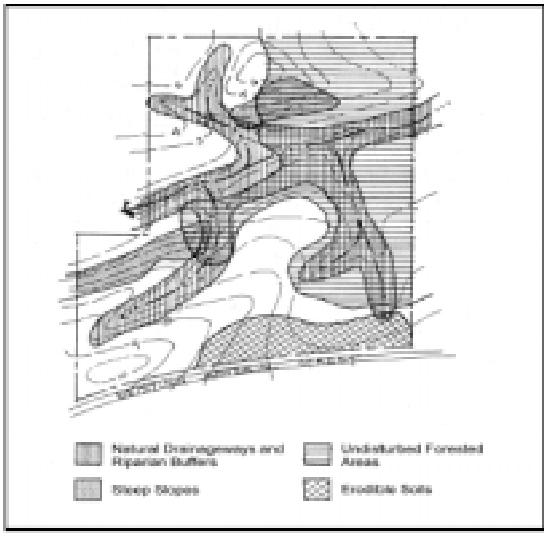


Figure 4.3.1.2-a Site map with natural areas delineated.
Source: Adapted from Atlanta Regional Commission, 2001.

Special Considerations

Riparian Buffers

A riparian buffer is a special type of preserved area along a watercourse where development is restricted or prohibited. Buffers protect and physically separate a watercourse from development. Riparian buffers also provide stormwater control flood storage and habitat values. An example of a riparian buffer is shown in Figure 4.3.1.2-b. Wherever possible, riparian buffers should be sized to include the 100-year floodplain as well as steep banks and freshwater wetlands.

Figure 4.2.1.2-b Riparian buffer. Source: Adapted from Atlanta Regional Commission, 2001

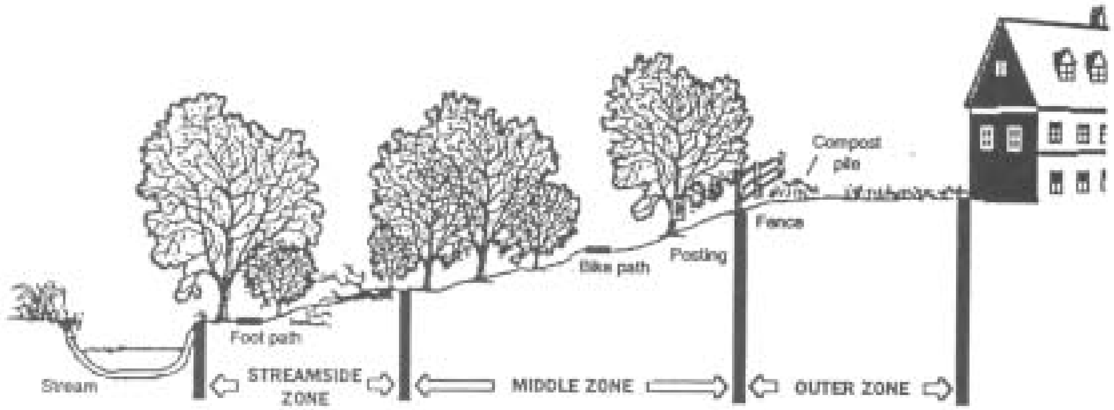


Figure 4.3.1.2-c Three-zone riparian buffer. Source: Adapted from Atlanta Regional Commission, 2001.

Riparian buffers consist of three zones (see Figure 4.3.1.2-c):

- The inner zone consists of the jurisdictional riverbank wetland and should have a width of no less than 100 feet from the edge of a flowing body of water less than 10 feet wide and no less than 200 feet from the edge of a flowing body of water greater than 10 feet wide. (For more information, refer to the *Rules and Regulations Governing the Administration and Enforcement of the Freshwater Wetlands Act*.) In addition to runoff protection, this zone provides bank stabilization as well as shading and protection for the stream. This zone should also include wetlands and any critical habitats, and its width should be adjusted accordingly.
- The middle zone provides a transition between upland development and the inner zone and should consist of managed woodland that allows for infiltration and filtration of runoff. A 25-foot width is recommended for this zone. Forested riparian buffers should be maintained and reforestation should be encouraged where no wooded buffer exists. Proper restoration should include all layers of the forest plant community, including understory, shrubs and groundcover, not just trees.
- An outer zone allows more clearing and acts as a further setback for impervious surfaces. It also functions to prevent encroachment and filter runoff. It is here that flow into the buffer should be transformed from concentrated flow into sheet flow to maximize ground contact with the runoff. A 25-foot width is recommended for this zone.

Generally, all three zones of the riparian buffer should remain in their natural state. However, some maintenance is periodically necessary, such as planting to minimize concentrated flow, the removal of exotic plant species when these species are detrimental to the vegetated buffer and the removal of diseased or damaged trees.

Floodplains
Floodplains are the low-lying flatlands that border streams and rivers. When a stream reaches its capacity and overflows its channel after storm events, the floodplain provides for storage and conveyance of these excess flows. In their natural state they reduce flood velocities and peak flow rates by the passage of flows through dense vegetation.

Floodplains also play an important role in reducing sedimentation and filtering runoff, and provide habitat for both aquatic and terrestrial life. Development in floodplain areas can reduce the ability of the floodplain to convey stormwater, potentially causing safety problems or significant damage to the site in question, as well as to both upstream and downstream properties.

As such, floodplain areas should be avoided on a development site. Ideally, the entire 100-year floodplain at full buildout should be avoided for clearing or building activities, and should be preserved in a natural undisturbed state where possible. Maps of the 100-year floodplain can typically be obtained through the local review authority.

Standards

General

a) No disturbance shall occur to preservation areas during project construction.
b) Preserved areas shall be protected by limits of disturbance clearly shown on all construction drawings and clearly marked on site.
c) Preservation areas shall be located within an acceptable conservation easement instrument that ensures perpetual protection of the proposed area. The easement must clearly specify how the natural area vegetation shall be managed and boundaries will be marked. [Note: managed turf (e.g., playgrounds, regularly maintained open areas) is not an acceptable form of vegetation management.]
d) Preservation areas shall have a minimum contiguous area of 10,000 square feet or in the case of stream buffers must maintain a 50-foot set back from the jurisdictional wetland edge along the entire length of stream through the property of concern. Areas of smaller size may be incorporated for disconnection of impervious surface, but will be considered as open space in good condition.
e) Incorporate level spreaders or other dispersion devices, where practicable, to ensure sheet flow. See Figure 4.3.1.2-d, which depicts a level speader.

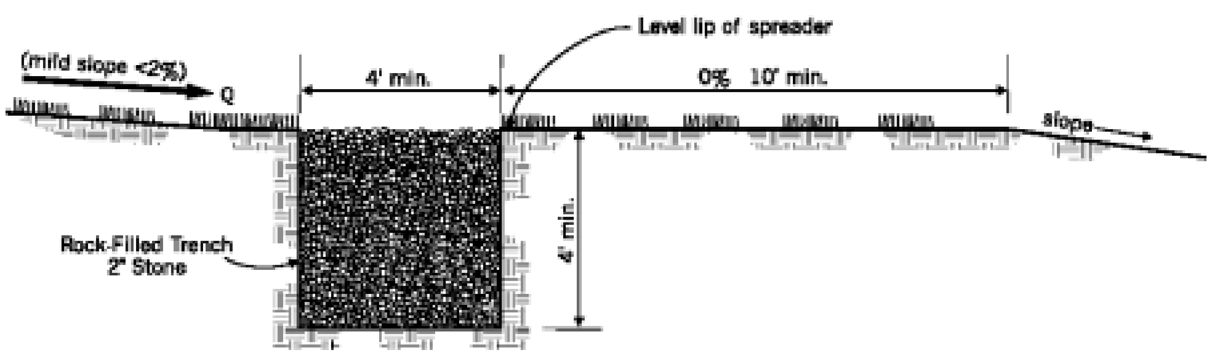


Figure 4.2.13.2-d Rock trench level spreader. Source: Prince George’s County, Maryland, 2000 (1)

f) Include bypass mechanisms for higher flow events to prevent erosion or damage to a buffer or undisturbed natural area.
g) Consider incorporating constructed berms around natural depressions and below undisturbed vegetated areas to provide for additional runoff storage and infiltration. Proper use of berms is discussed in the section entitled vegetated filter strips.

h) Where no berms are provided in HSG type A and B soils, buffers may be used to attenuate and treat flows up to the water quality volume (i.e., volume equal to one inch over the impervious surface) in the following ratios:

Table 4.3.1.2-1
Units of Forested Buffer Necessary to Attenuate Runoff from a Unit of Impervious Surface for Precipitation Between 0.5 and 1.0 Inches[a, b]

Precipitation (inches)	HSG Soil Type			
	A	B	C	D
1.0	1/3	2	N/A	N/A
0.9	1/4	1	N/A	N/A
0.8	1/6	1	N/A	N/A
0.7	1/8	1/2	N/A	N/A
0.6	1/8	1/4	1	N/A
0.5	1/8	1/8	1/2	N/A

Notes:
[a]Buffer size calculations based on TR-55. Calculations for precipitation depths less than 0.5 inches are not included as the empirical equations of TR-55 become less accurate for storms less than 0.5 inches.
[b]Standards for buffer width, area and length of contributing flow path, etc. must be met regardless of soil's capacity to attenuate flow.

i) Land cover in buffers will be assumed to be woods in good condition (i.e., CN equal to 32 in type A soil and 55 in type B soil). Type C and D may not be used for this purpose as woods on these soil types cannot abstract the depth of rainfall associated with one inch of runoff from the impervious surface.
j) Runoff must enter the buffer as overland sheet flow. The average contributing slope should be no less than 1% and no more 3%. Maximum average slope may be increased to 5% if a flow spreader is installed across the entire contributing length followed by a flat (i.e., 0% slope) 10-foot shelf across the length.

Streambank Areas
a) The minimum undisturbed buffer width shall be at least the wetland jurisdictional setback plus 50 feet (e.g., 150 feet for streams less than 10 feet wide).
b) The maximum length of area contributing runoff may no more be 150 feet for pervious surfaces and 75 feet for impervious surfaces. The minimum contributing length should be no less than 20 feet.

Maintenance
Except for routine debris removal, buffers shall remain in a natural and unmanaged condition.

4.3.1.3 Avoid Disturbing Long, Steep Slopes

Disturbance of long, steep slopes tends to cause soil erosion. Studies show that soil erosion is significantly increased on slopes of 15% or greater. In addition, the geometry of steep slopes means that greater surface areas are disturbed to locate facilities on them compared to flatter slopes as demonstrated in Figure 4.3.1.3-a.

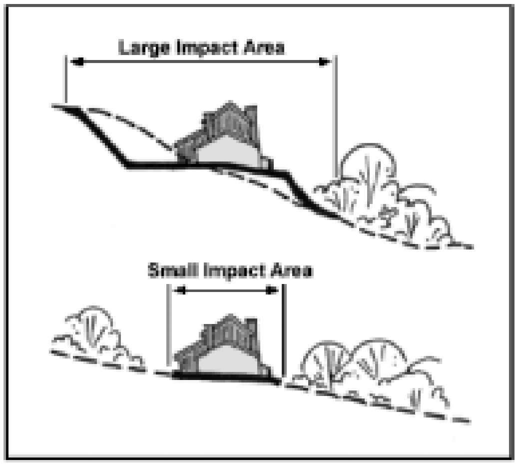


Figure 4.3.1.3-a Building on flatter slopes reduces the impact of development. Source: Adapted from Atlanta Regional Commission, 2001.

Advantages

- Prevents soil erosion and sedimentation.
- Stabilizes hillsides and soils.
- Reduces the need for cut-and-fill and grading and may substantially reduce cost of development.

Standards

a) Avoid development on steep slope areas. As a general rule do not exceed the following values:

Grade	Slope Length
0% - 7%	300 feet
7% - 15%	150 feet
over 15%	75 feet

(Prince George's County, 2000)

b) On slopes greater than 25% (Georgia, 2000), no development, regrading, or stripping of vegetation should be considered unless the disturbance is for roadway crossings or utility construction. Erosion hazard risk increases as follows:

Grade	Erosion Risk

0% - 7%	Low
7% - 15%	Moderate
over 15%	High

(Prince George's County, 2000)

c) Unnecessary grading should be avoided on all slopes, as should the flattening of hills and ridges.
d) After cutting out soils, avoid inverting the soil horizons while filling.

4.3.1.4 Minimize Siting on Porous and Erodible Soils

This technique discusses appropriate standards for managing development in areas of erodible and porous soils.

Advantages

- Areas with highly permeable soils can be used as nonstructural stormwater infiltration zones.
- Avoiding highly erodible or unstable soils can prevent erosion and sedimentation problems and water quality degradation.
- Infiltration of stormwater into the soil reduces both the volume and peak discharge of runoff as well as groundwater recharge.
- Infiltration provides for water quality treatment.

Use

a) Use soil surveys to determine site soil types.
b) Delineate hydrologic soil types on concept site plans to guide site layout and the placement of buildings and impervious surfaces (see Figure 4.3.1.4-a).

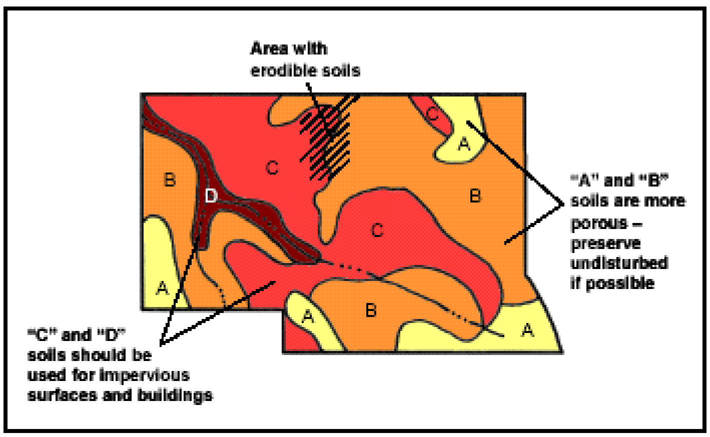


Figure 4.2.1.4-a Site plans depicting hydrologic soil groups.

Standards

a) Whenever possible, leave areas of porous or highly erodible soils (hydrologic soil group A and B soils such as sandy and silty soils) as undisturbed conservation areas (see Preserve Natural Areas for more information on conservation areas).
b) Conversely, buildings and other impervious surfaces should be located on those portions of the site with the *least* permeable soils. Gravel soils tend to be the least erodible. Also as clay and organic matter increase erodibility tends to decrease.

4.3.2 Working with Site Hydrology

Nonstructural and distributed BMPs mimic natural predevelopment hydrology in order to retain and attenuate stormwater runoff in upland areas. This reduces the amount of stormwater and intensity of flow at points of discharge. Flow attenuation prevents physical damage to waterways and reduces nonpoint source pollution.

Advantages

- Decreased need for constructed BMPs.
- Maintains predevelopment hydrology and thus reduces generation of stormwater and associated pollution.
- Encourages groundwater recharge.

Use

Mimicking predevelopment site hydrology involves a process of comparing and evaluating pre- and postdevelopment conditions that takes place in all stages of site planning. There are many methods of hydrologic analysis. This section of the manual relies on the use of the USDA-SCS Technical Release-55 (TR-55), entitled *Urban Hydrology for Small Watersheds* (1986).

Time of Concentration and Time of Travel

TR-55 focuses on the time of concentration (Tc) as a primary influence in the shape and peak of runoff hydrographs. TR-55 defines time of concentration as the "time for runoff to travel from the hydraulically most distant point of the watershed to a point of interest within the watershed."

Tc is calculated as follows:

$$Tc = Tt(1) + Tt(2) + \ldots Tt(m)$$

Where:

Tt (travel time) is the time it takes runoff to move across a segment of the watershed.

m is the total number of travel segments in a watershed

Tt is mathematically defined by TR-55 as being directly influenced by two factors velocity of runoff (V) and length of runoff flow path (L). Velocity is further defined as a function of slope (s) and surface roughness (i.e., Manning's roughness coefficient) (n).

Tt is calculated as follows:

$$Tt = \frac{L}{3600\ V}$$

Where:

Tt = travel time in hours
L = flow length in feet
V = average velocity in feet per second
3600 = conversion factor for seconds to hours

Total Volume and Peak Discharge

TR-55 also notes that total runoff volume (Q) and peak runoff discharge (qp) tend to increase as a result of urbanization. Peak discharge is defined as a factor of Q and can be calculated using as follows:

$$qp = qu\ Am\ Q\ Fp$$

Where:

qp = peak discharge in cubic feet per second
qu = unit peak discharge
Am = drainage area in square miles
Q = runoff in inches
Fp = pond and swamp adjustment factor

Q is derived as a factor of initial abstraction (Ia) and retention (S) and is calculated as follows:

$$Q = \frac{(P - Ia)^2}{(P - Ia) + S}$$

Where:

Q = runoff in inches
P = rainfall in inches
S = retention
Ia = initial abstraction

Initial abstraction is a measure of rainfall held in surface depressions, interception by vegetation, evapotranspiration and infiltration prior to the occurrence of runoff and is calculated as follows:

$$Ia = 0.02\ S$$

Where:

Ia = initial abstraction
S = retention

Retention is a measure of total capacity for rainwater storage in a watershed during a rain event. In small agricultural watersheds retention is typically about 5 times greater than initial abstraction.

Retention is calculated as follows:

$$S = \frac{1000}{CN} - 10$$

Where:

S = retention
CN = curve number

Curve number is a coefficient ranging from 0 - 100, which is used to represent the conversion of rainfall to runoff. For example, an impervious surface such as concrete has a CN of 98, which is analogous to representing that 98% of rain that falls on concrete runs off.

Identifying Hydrologic Benefits

All nonstructural and distributed BMPs have one or more hydrologic benefits in relationship to TR-55. Table 4.3.2-1 (below) summarizes key hydrologic benefits of nonstructural and distributed BMPs recommended in this manual.

Table 4.3.2-1
Hydrologic Benefits of
Nonstructural and Distributed Techniques and Controls

Techniques & Controls	Decrease Curve Number	Reduce Slope	Lengthen Flow Path	Increase Roughness	Increase Initial Abstraction	Increase Total Retention
Reduce Limits of Clearing and Grading	●[a]		◖[b]	●	●	
Preserve Natural Features	●		●	●	●	
Avoid Long, Steep Slopes		●	◖		●	
Avoid Erodible Soils				●	●	
Avoid Porous Soils	◖			●	●	
Minimize Roadways	●		◖	●	●	
Minimize Buildings	●		●	●	●	
Minimize Parking	●		●	●	●	
Disconnect Impervious Area	●		◖	◖	●	
Buffers and Undisturbed Areas	●		●	●	●	●

Infiltration Swales	●	◖	◖	●	●	●
Vegetative Filter Strips	●			●	●	●
Bioretention	●				●	●
Nonstructural Conveyances	●		◖	●	●	
Drain Rooftop Runoff to Pervious Areas			●	●	●	
Rain Barrels and Cisterns					●	●
Dry Wells					●	●
Green Roofs and Walls					●	●

Notes
[a] Benefit always occurs.
[b] Benefit occurs sometimes.

Standards

Time of Concentration
The postdevelopment time of concentration (Tc) should approximate the predevelopment Tc.

Travel Time
The travel time (Tt) throughout individual lots and areas should be approximately constant.

Flow Velocity
Flow velocity in areas that are graded to natural drainage patterns should be kept as low as possible to avoid soil erosion.

Flows can be disbursed by installing a level spreader along the upland ledge of the natural drainage way buffer, and creating a flat grassy area about 30 feet wide on the upland side of the buffer where runoff can spread out. This grassy area can be incorporated into the buffer itself.

4.3.3 Minimizing and Disconnecting Impervious Surface

4.3.3.1 Roadways

The greatest share of impervious cover in most communities is from paved surface such as roads and sidewalks. Roadway lengths and widths should be minimized on a development site where possible to reduce overall imperviousness.

Numerous alternatives create less impervious cover than the traditional 40-foot cul-de-sac. These alternatives include reducing cul-de-sacs to a 30-foot radius and creating hammerheads, loop roads, and pervious islands in the cul-de-sac center (see Figure 4.3.3.1-a, b and c).

Figure 4.3.3.1-a alternative roadway designs. Source: Adapted from Atlanta Regional Commission, 2001.

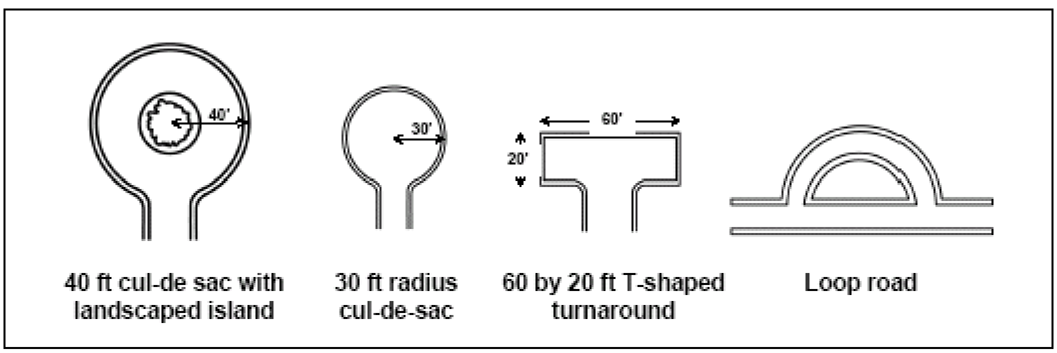


Figure 4.3.3.1-g Different styles of turnarounds. Source: Adapted from Atlanta Regional Commission, 2001.

Advantages

- Reduces the amount of impervious cover and associated runoff and pollutants generated.
- Reduces the costs associated with road construction and maintenance.

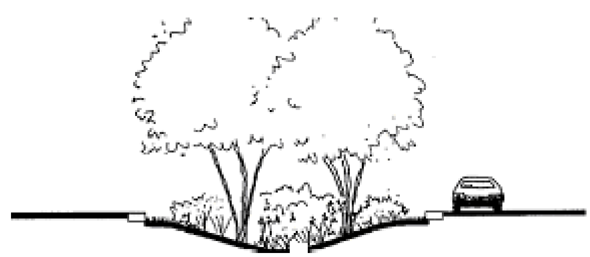


Figure 4.3.3.1-c Cul-de-sac infiltration island accepts stormwater from surrounding pavement. Note flat curb. Source: Adapted from Connecticut, 2004.

Use

Examine local ordinances and other requirements to determine standards and degree of flexibility available. Communities may have specific standards for setbacks and frontages or criteria for cul-de-sacs and other alternative turnarounds.

Reduce Roadway Lengths and Widths

1. Consider site and road layouts that reduce overall street length.
2. Minimize street width by using narrower street designs as appropriate. Issues to consider include design speed, number of average daily trips (ADT), peak usage, need for on-street parking, sidewalks, design speed and right of way (see Table 4.3.3.1-1 and Figure 4.3.3.1-d).

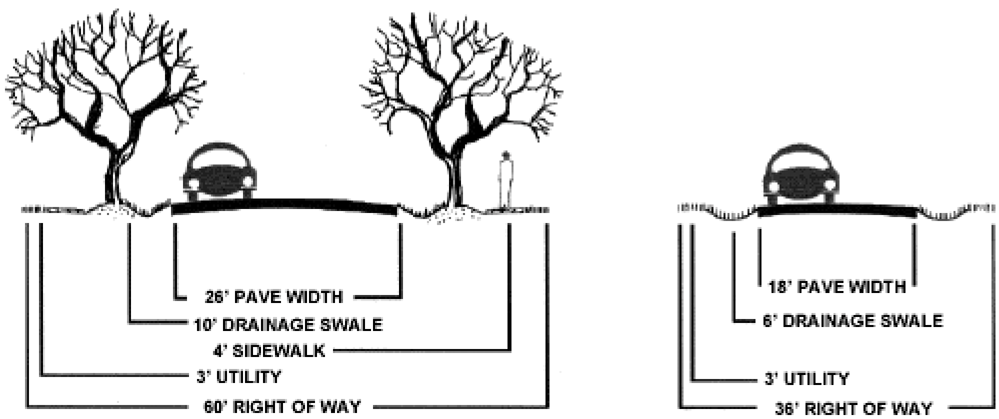


Figure 4.3.3.1-d Reduced road widths. Source: Adapted from Atlanta Regional Commission, 2001.

Reduce Surface Area of End-of-Street Turnarounds

1. Consider types of vehicles that may need to access a street. Sufficient turnaround area is a significant factor to consider in the design of cul-de-sacs. Fire trucks, service vehicles and school buses are often cited as needing large turning radii. However, some fire trucks are designed for smaller turning radii. In addition, many newer large service vehicles are designed with a tri-axle (requiring a smaller turning radius) and school buses usually do not enter individual cul-de-sacs.
2. Minimize pavement at end-of-street turnarounds. Incorporate landscaped areas and consider alternatives to cul-de-sacs where ever practicable.

Standards

Reduce Roadway Lengths and Widths

The table below shows a recommended standard for five categories of street. Table 4.3.3.1-1 is based on Table 35 of *Site Planning for Urban Stream Protection* (Schueler, 1995). Streets are categorized based on ADT and density of dwelling units (row 1 in the table). These standards should be applied wherever permitted by local zoning.

Table 4.3.3.1-1
Roadway Design Standards for Five Street Types

Design Factor	Lane	Access	Standard Street	Dense Street	Collector
ADT	Less than 100	100 - 500	500 - 1,000	100 - 1,000 @ 4 dwell units/acre	1,000 - 3,000
Width (feet)	16	20	26	32	22 - 28
Extra ROW (feet)	8 - 16	8 - 24	20	20	22 - 28
Off-Street Parking	None	One lane	One lane	Two lane	Emergency shoulders
Drainage	Swale	Swale or curb/gutter	Curb/gutter	Curb/gutter	Swale or shoulder
Design Speed (MPH)	15	20	25	25	25
Sidewalks	None	One side	One or two side	Two side	One side
Frontage Lots	Yes	Yes	Yes	Yes	No

Equation 4.3.3.1(a) Average Daily Trips
ADT = 10 x Number of Dwelling Units

Equation 4.3.3.1(b) Peak Trips Per Hour
Peak Trips/Hour = Number of Dwelling Units

Reduce Surface Area of End-of-Street Turnarounds

Wherever practicable cul-de-sac radii should be no more than 30 feet. Alternatives such as hammerheads, jughandles and donuts should also be considered.

4.3.3.2 Buildings

Imperviousness associated with buildings and accessories such as driveways can often be reduced with considerate planning in the early stages of site design. The techniques below should be considered and applied wherever practicable.

Advantages

- Reduces the amount of impervious cover and associated runoff and pollutants generated.

Discussion

Footprints

The building footprint is the surface area of ground covered by structure. The impervious footprint of commercial buildings and residences can be reduced by using tall buildings. In comparison to single-story buildings, multistory buildings maintain floor area while covering less ground surface. Use alternate or taller building designs to reduce the impervious footprint of buildings. For example, in residential areas consider colonial style homes instead of ranches.

Setbacks and Frontages

Driveways generally extend from a roadway to a house. Therefore, driveway length is typically determined by building setback requirements. Driveways are noted to contribute up to 30 percent of impervious cover in residential areas (Scheuler, 1995). Setback requirements of up to 75 feet are not uncommon. Notwithstanding a driveway length of 20 to 30 feet is generally adequate to meet parking needs. A driveway width of 18 feet is generally adequate for parking two cars side-by-side.

Further, reducing side-yard widths and using narrower frontages can reduce total street length, especially important in cluster and open space designs. Figure 4.3.3.2-a shows residential examples of reduced front and side yard setbacks and narrow frontages.

Figure 4.3.3.2-a Reduced front and side yards can be very aesthetically pleasing. Source: Adapted from Atlanta Regional Commission, 2001.

Flexible lot shapes and setback and frontage distances allow site designers to create attractive and unique lots that provide homeowners with enough space while allowing for the preservation of natural areas in a residential subdivison. Figure 4.3.3.2-b illustrates various nontraditional lot designs.

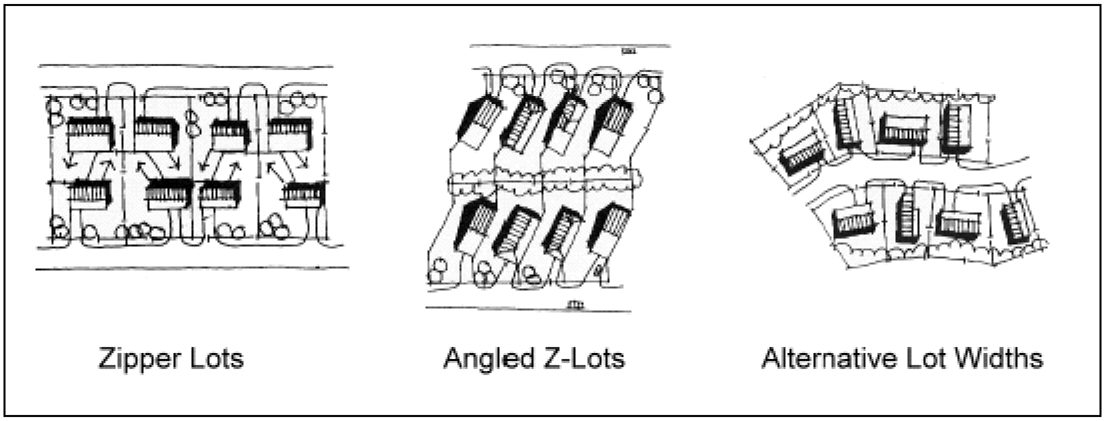


Figure 4.3.3.2-b Examples of nontraditional lot designs. Source: Adapted from Atlanta Regional Commission, 2001.

Use

Use smaller front and side setbacks and narrower frontages to reduce total road length and driveway lengths.

Reduce building and home front and side setbacks to allow for narrow frontages. Consider narrower frontages.

a) Consider alternative build styles that reduce ratio of footprint to floor area.
b) Review local regulations. Communities may have specific design criteria for setbacks and frontages.
c) Minimize setbacks and lot frontages.

Standards

a) Where practicable, reduce building setbacks to 20 - 30 feet and driveway widths to 18 feet.
b) Where practicable, reduce frontages to 60 feet.

4.3.3.3 Parking Footprints

Setting maximums for parking spaces, minimizing stall dimensions, using structured parking and encouraging shared parking and using alternative porous surfaces can reduce the overall parking footprint and site imperviousness.

Advantages

- Reduces the amount of impervious cover and associated runoff and pollutants generated.

Use and Standards

Apply the following approach:

Examine local ordinances and other requirements to determine standards and degree of flexibility available. Communities may have specific standards for parking stall size and number of parking spaces. There may also be prohibitions against shared parking.

Use Average Demand to Size Lots

a) Many parking lot designs result in far more spaces than actually required. This problem is exacerbated by a common practice of setting parking ratios to accommodate the highest hourly parking during the peak season. By determining average parking demand instead, a lower maximum number of parking spaces can be set to accommodate most of the demand.
b) If no local standards require a minimum number of spaces, apply the standards in Table 4.3.3.3-1 as a maximum number of spaces.

Table 4.3.3.3-1
Recommended Maximum Number of Parking Spaces for Certain Land Uses

Land Use	Maximum Parking Spaces
Single Family House	2 per DU[a]
Shopping Center	5 per 1000 ft^2 GFA[b]
Convenience Store	3.3 per 1000 ft^2 GFA
Industrial	1 per 1000 ft^2 GFA
Medical Dental	5.7 per 1000 ft^2 GFA

Notes
Source: Georgia Stormwater Manual, 2002.
[a] DU means dwelling unit.
[b] GFA means gross floor area.

Minimize Parking Stall Size

Another technique to reduce the parking footprint is to minimize the dimensions of the parking spaces. This can be accomplished by reducing both the length and width of the parking stall.

Parking stall dimensions can be further reduced if compact spaces are provided. While the trend toward larger sport utility vehicles (SUVs) is often cited as a barrier, stall width requirements in most local parking codes are much larger than the widest SUVs.

Use Parking Decks

Structured parking decks can significantly reduce the overall parking footprint by minimizing surface parking. Figure 4.3.3.3-a shows a parking deck used for a commercial development.

Figure 4.3.3.3-a Parking deck. Source: Adapted from Atlanta Regional Commission, 2001.

Encourage Shared Parking

Shared parking in mixed-use areas and structured parking are techniques that can further reduce the conversion of land to impervious cover. A shared parking arrangement could include usage of the same parking lot by an office space that experiences peak parking demand during the weekday with a church that experiences parking demands during the weekends and evenings.

4.3.3.4 Parking Lot Islands

A parking lot island is an area within a parking lot that includes one or more management practices and breaks up impervious surface (see Figure 4.3.3.4-a). Parking lot islands include small-scale management practices such as filter strips, dry swales, sand filters and bioretention.

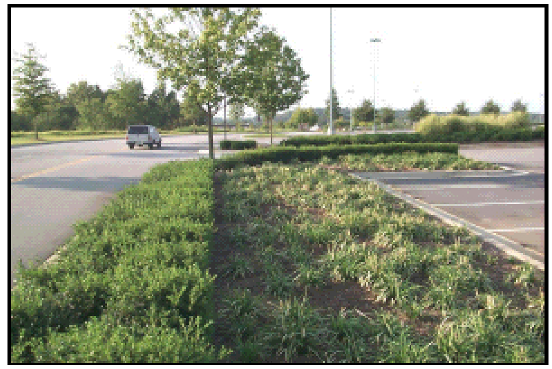


Figure 4.3.3.4-a Parking lot island. Source: Adapted from Atlanta Regional Commission, 2001.

Advantages

- Reduces the amount of impervious cover and associated runoff and pollutants generated.
- Provides an opportunity for the siting of structural control facilities.
- Trees in parking lots provide shading for cars and are more visually appealing.

Use

Break up expanses of parking with landscaped islands, which include shade trees and shrubs. Fewer large islands will sustain healthy trees better than more numerous very small islands.

Structural control facilities such as filter strips, dry swales and bioretention areas can be incorporated into parking lot islands. Stormwater is directed into these landscaped areas and temporarily detained. The runoff then flows through or filters down through the bed of the facility and is infiltrated into the subsurface or collected for discharge into a stream or another stormwater facility. These facilities can be attractively integrated into landscaped areas and can be maintained by commercial landscaping firms. For detailed design specifications of filter strips, enhanced swales and bioretention areas, refer to chapter 11.

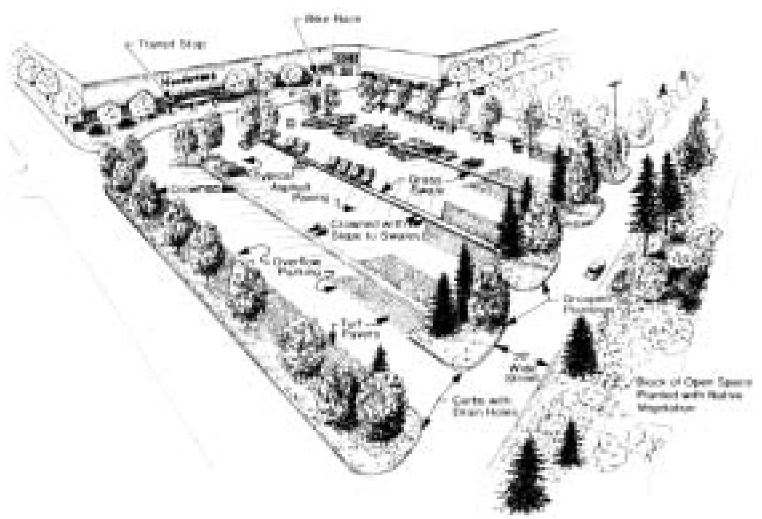


Figure 4.3.3.4-b Parking lot with islands attractively integrated. Source: Adapted from Connecticut, 2004.

Standards

Parking lot islands should:

a) Be at least 8 feet wide.
b) Be constructed with sub-surface drainage.
c) Incorporate compaction resistant soil.

4.3.3.5 Permeable Pavement

Permeable pavement is designed to allow rain and snowmelt to pass through it, thereby reducing runoff, promoting groundwater recharge, and filtering pollutants. Permeable paving materials include:

- Modular concrete paving blocks
- Modular concrete or plastic lattice
- Cast-in-place concrete grids
- Soil enhancement technologies
- Other materials such as gravel, cobbles, wood, mulch, brick, and natural stone.

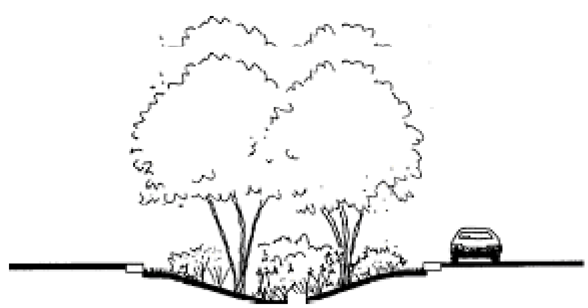
Figure 11-S6-1 illustrates examples of common permeable pavement applications.

Porous asphalt or concrete (i.e., porous pavement), which look similar to traditional pavement but are manufactured without fine materials and incorporate additional void spaces, are only recommended for certain limited applications in Connecticut due to their potential for clogging and high failure rate in cold climates. Porous pavement is only recommended for sites that meet the following criteria:

Low traffic applications (generally 500 or fewer average daily trips or ADT).
The underlying soils are sufficiently permeable (see Design Considerations below).
Road sand is not applied.

Runoff from adjacent areas is directed away from the porous pavement by grading the surrounding landscape away from the site or by installing trenches to collect the runoff.
Regular maintenance is performed (sweeping, vacuum cleaning).

Advantages



- Reduces the amount of impervious cover and associated runoff and pollutants generated.
- Reduces the costs associated with road construction and maintenance.

Use

a) Applicable to small drainage areas.
b) Low traffic (generally 500 ADT or less) areas of parking lots (i.e., overflow parking for malls and arenas), driveways for residential and light commercial use, walkways, bike paths, and patios.

c) Roadside right-of-ways and emergency access lanes.
d) Useful in stormwater retrofit applications where space is limited and where additional runoff control is required.
e) In areas where snow plowing is not required.

Standards

Permeable pavement is a type of infiltration practice similar to those discussed in chapter 11. Many of the siting, design, construction, and maintenance considerations for permeable pavement are similar to those of other infiltration practices. In addition, modular pavers and grids should be installed and maintained in accordance with the manufacturer's instructions. General considerations for permeable pavement are summarized below:

Soils
Permeable pavement should only be used with soils having suitable infiltration capacity as confirmed through field testing. Field-measured soil infiltration rates should be at least 0.3 inches per hour. Percolation should be complete within 48 hours (Pennsylvania Association of Conservation Districts et al., 1998). Field-measured soil infiltration rates should not exceed 5.0 inches per hour to allow for adequate pollutant attenuation in the soil. This generally restricts application to soils of NRCS Hydrologic Soil Group A. Some Group B soils may be suitable if field-measured infiltration rates exceed 0.3 inches per hour. Refer to the Infiltration Practices section of this chapter for recommended field measurement techniques. Permeable pavement should not be used on fill soils or soils prone to frost action.

Land Use
Permeable pavement should not be used in public drinking water aquifer recharge areas or where there is a significant concern for groundwater contamination. Exceptions may include certain "clean" residential applications where measures are taken to protect groundwater quality (e.g., residential driveways or walkways graded to drain away from the permeable pavement). Permeable pavement is not appropriate for land uses where petroleum products, greases, or other chemicals will be used, stored, or transferred. Permeable paving materials should not be used in areas that receive significant amounts of sediment or areas that require sand and salt application for winter deicing.

Slope
Permeable pavement should not be used in areas that are steeply sloped (>15%), such as steep driveways, as this may lead to erosion of the material in the voids.

Water Table/Bedrock
The seasonally high water table or bedrock, as documented by on-site soil testing, should be at least 3 feet below grade. Permeable pavement should be located at least 100 feet from drinking water wells.

Construction

Manufacturer's guidelines should be followed for installation. Generally, the following procedures are followed for construction of modular pavement systems:

Site Preparation

- Site must be excavated and fine graded to the depth required by the base design.
- Roller pressure should be applied to compact soils.
- Base rock (3" to 6" of ¾" clean gravel) is then installed and compacted to approximately 95% of Standard Proctor Density.
- A 1" sand layer is placed on top of the gravel layer and compacted.
- The pavers are then installed according to manufacturer's requirements.

Planting

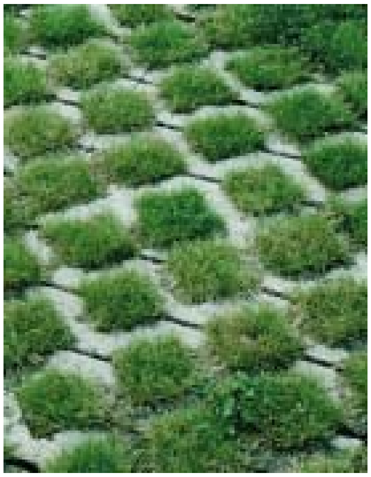
- At least 1/8" to ¼" of the paver must remain above the soil to bear the traffic load.
- Sod or seeding method may be used.
- If sod is used, the depth of backfill required will depend on the depth of the sod. Sod is laid over the pavers, watered thoroughly, and then compressed into the cells of the pavers.
- If grass is planted from seed, the appropriate soil should be placed in the cells, tamped into the cells, and then watered thoroughly so that the appropriate amount of paver is exposed. The soil is then ready for planting with a durable grass seed.
- Traffic should be excluded from the area for at least a month to allow for establishment of grass.

Operation and Maintenance

Permeable pavement is easiest to maintain in areas where access to the pavement is limited and controlled and where pavement maintenance can be incorporated into a routine site maintenance program such as commercial parking lots, office buildings, and institutional buildings (Pennsylvania Association of Conservation Districts et al., 1998). Turf pavers can be mowed, irrigated, and fertilized like other turf areas. However, fertilizers and other chemicals may adversely affect concrete products, and the use of such chemicals should be minimized. Pavers should be inspected once per year for deterioration and to determine if soil/vegetation loss has occurred. Soil or vegetation should be replaced or repaired as necessary. Care must be exercised when removing snow to avoid catching the snowplow on the edges of the pavers. Permeable pavement should be regularly cleared of tracked mud or sediment and leaves.

Plans for permeable pavement should identify detailed inspection and maintenance requirements, inspection and maintenance schedules, and those parties responsible for maintenance.

Figure 11-S6-1. Examples of Permeable Pavement Applications



Modular Concrete Pavers

Parking Lot with Porous Surface

Overflow Parking Area

Concrete Paver Driveway

Low Use Parking Area

Plastic Lattice Turf Pavement

Source: Nonpoint Education for Municipal Officials (NEMO) web site.

References

Metropolitan Council. 2001. *Minnesota Urban Small Sites BMP Manual: Stormwater Best Management Practices for Cold Climates.* Prepared by Barr Engineering Company. St. Paul, Minnesota.

Nonpoint Education for Municipal Officials (NEMO) website, URL: http://nemo.uconn.edu.

Pennsylvania Association of Conservation Districts, Keystone Chapter Soil and Water Conservation Society, Pennsylvania Department of Environmental Protection, and Natural Resources Conservation Service. 1998. *Pennsylvania Handbook of Best Management Practices for Developing Areas.* Prepared by CH2MHILL.

Schueler, T.R., Kumble, P.A., and M.A. Heraty. 1992. *A Current Assessment of Urban Best Management Practices: Techniques for Reducing Non-Point Source Pollution in the Coastal Zone.* Department of Environmental Programs. Metropolitan Washington Council of Governments.

4.3.3.5 Disconnecting Impervious Areas

Impervious surfaces that are separated from drainage collection systems by pervious surface or infiltrating BMPs contribute less runoff and reduced pollutant loading. Isolating impervious surface promotes infiltration and filtration of stormwater runoff.

Advantages

- Promotes evapotranspiration and infiltration to reduce need for treatment and peak volume control at end-of-pipe.
- Reduces generation of stormwater.
- Maintains predevelopment hydrology, natural character and aesthetic features that may increase market value.

Use

Use the following techniques to disconnect impervious surface from collection systems:

a) Direct roof runoff and runoff from paved surfaces to stabilized vegetated areas such as buffers.
b) Direct runoff from large impervious surfaces (over 5000 square feet) to more than one receiving area.
c) Encourage sheet flow through vegetated areas.

Standards

General

a) Disconnect impervious surfaces to the extent practicable.
b) Up to the first inch of runoff from an impervious surface may be disconnected to a pervious surface such as a lawn.

Table 4.3.3.5-1
Units of Open Space Necessary to Attenuate Runoff from a Unit of Impervious Surface for Precipitation Between 0.5 and 1.0 Inches[a, b]

Precipitation (inches)	HSG Soil Type			
	A	B	C	D
1.0	1/2	N/A	N/A	N/A
0.9	1/3	2	N/A	N/A
0.8	1/4	1	N/A	N/A
0.7	1/8	1/2	N/A	N/A
0.6	1/8	1/3	N/A	N/A
0.5	1/8	1/6	1	N/A

Notes:
[a]Buffer size calculations based on TR-55. Calculations for precipitation depths less than 0.5 inches are not included as the empirical equations of TR-55 become less accurate for storms less than 0.5 inches.
[b]Standards for buffer width and length of contributing flow path, etc. must be met regardless of soil's capacity to attenuate flow.

c) Relatively permeable soils (hydrologic soil groups A and B) must be present for disconnection. Assume that the pervious surface is open space in good condition (i.e., CN of 39 for HSG A and 61 for HSG B). (If a forested buffer is being used refer to "Preserving Natural Areas" for appropriate standards.) The following impervious to pervious area ratios should be used. Type C and D may not be used for this purpose as open space on these soil types does not abstract the rainfall required to generate one inch of runoff from the impervious surface.
d) The maximum contributing impervious flow path length should be no more than 75 feet.
e) The disconnected area should drain continuously through a vegetated channel, swale, or filter strip to the property line or structural stormwater control.
f) Flow from the impervious surface must enter the downstream pervious area as sheet flow.
g) The length of the disconnected area should be equal to or greater than the contributing length.
h) The entire disconnected area should maintain a slope less than or equal to 5 percent.
i) The surface of the contributing imperviousness area should not exceed 5,000 square feet.

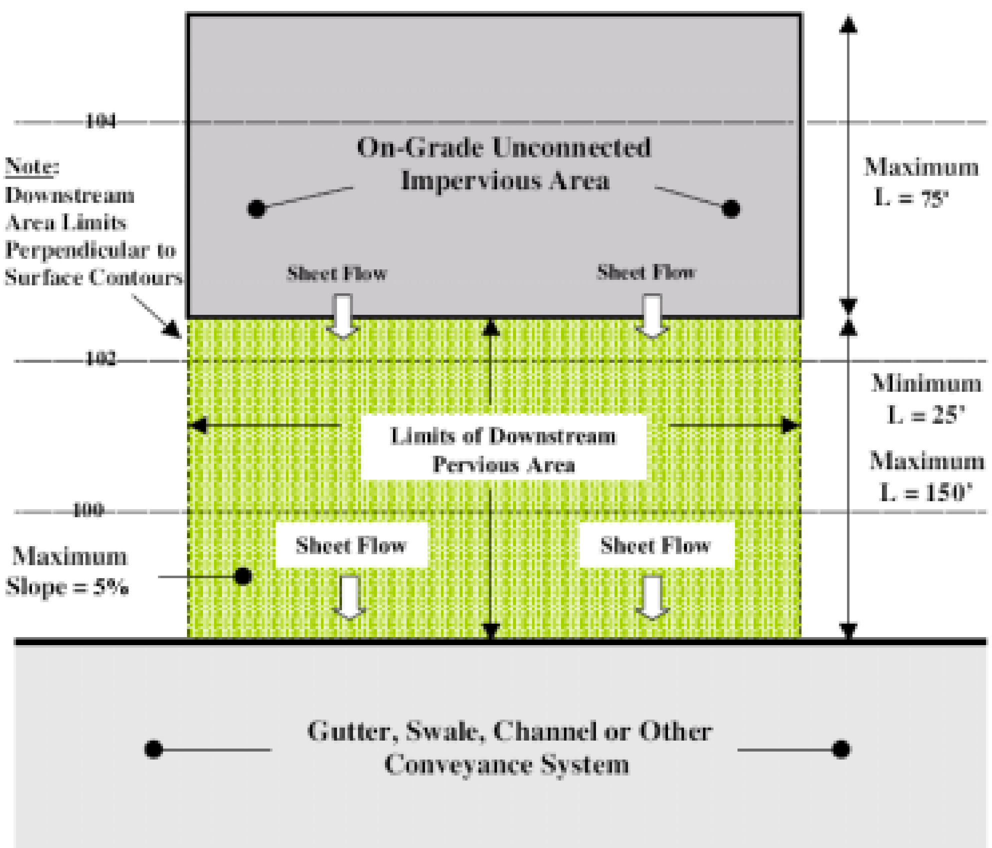


Figure 4.3.3.5-a Standards for disconnecting impervious surface via sheet flow.
Source: Adapted from New Jersey Department of Environmental Protection, 2004.

Downspouts

a) Downspout outfall expands in width at a rate of 1:4 for a maximum length of 100 feet and a minimum length of 25 feet.
b) No downspout may drain more than 600 square feet of roof.
c) Downspouts should be at least 10 feet away from the nearest impervious surface (e.g., driveways) to discourage reconnections to those surfaces.
d) Downspouts must be equipped with splash pads, level spreaders, or dispersion trenches that reduce flow velocity and induce sheet flow in the downstream pervious area.

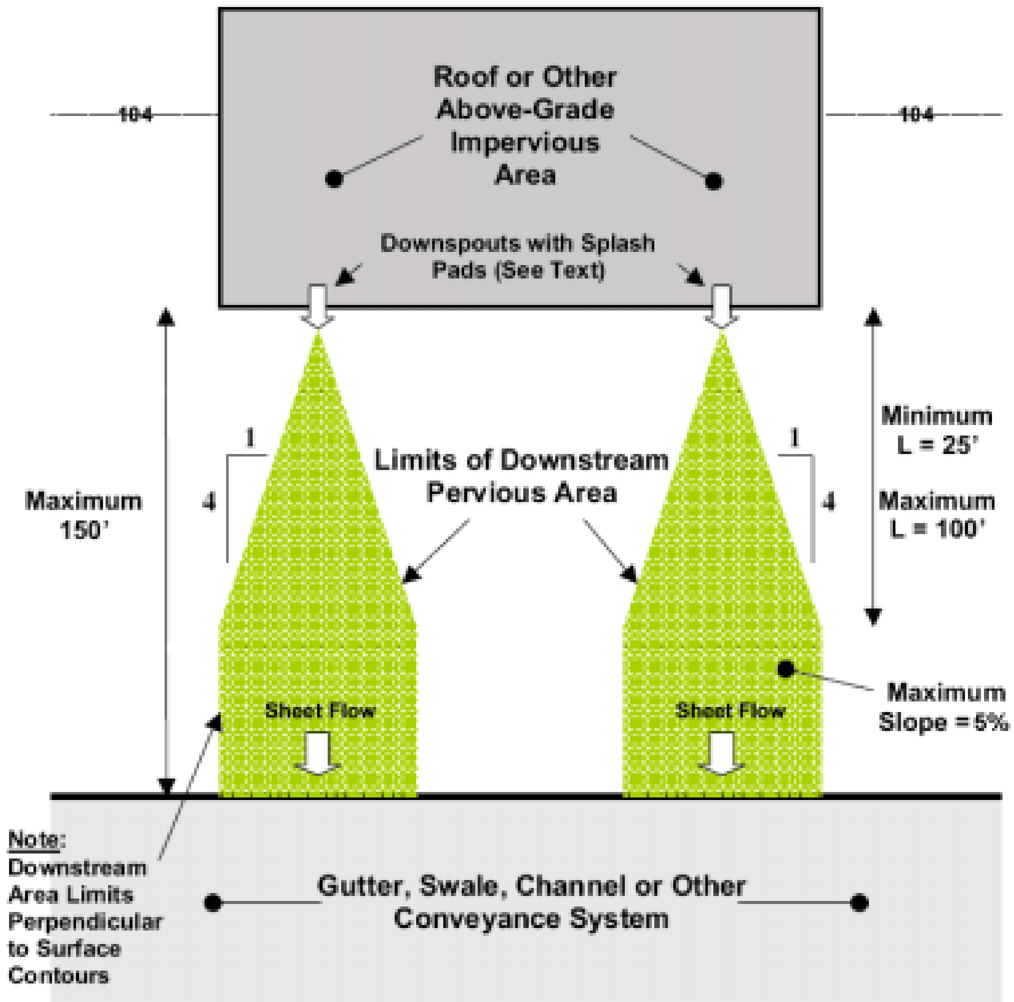


Figure 4.3.3.5-b Standards for disconnecting impervious surface via downspouts. Source: Adapted from New Jersey Department of Environmental Protection, 2004.

4.3.4 Applying Small-Scale Controls at the Source

4.3.4.1 Vegetated Filter Strips

A vegetated filter strip is an undisturbed densely vegetated area (e.g., well-tended lawn) contiguous with a developed area. These filter strips are most often located between a water resource and the developed portion of a site (see Figure 4.3.4.1-a).

Figure 4.3.4.1-a Vegetative filter strip. Source: Adapted from Connecticut, 2004.

Advantages

Filter strips serve to improve runoff water quality, add or maintain wildlife habitat, and provide a screening effect for homeowners. This type of BMP is best suited for complementing other structural methods utilized on-site for stormwater management.

Use

Filter strips can be composed of an undisturbed-forested area or created from disturbed land by proper seeding and plantings. The most effective pollutant removal filter strip is composed of dense grass vegetation that is properly maintained.

Channelization of runoff within the filter strip significantly reduces the amount of infiltration and subsequent pollutant removal. Filter strips must have a level spreading device incorporated into the design. Caution must be used when installing level spreaders to ensure long-term even flow and distribution of runoff to the filter strip. See Figure 4.3.1.2-d for example of a level spreader. Low volume pedestrian pathways may be constructed through a buffer strip, provided they are no greater than 4 feet wide and take a winding course to reduce the potential for channelized runoff flow. Pesticides should not be applied in these areas, although minimal fertilizer use is acceptable to help seeded areas become more quickly established. Incorporating organic material, such as mulch, into the topsoil is encouraged to promote better filter strip performance.

Soils with a high content of organic material will attenuate greater amounts of pollutants from stormwater runoff.

Standards

Site Suitability

a) Individual filter strips should only serve contributing areas of 1/4 to 5 acres to reduce the potential for concentrated and erosive stormwater flows. Sites larger than 5 acres would be required to use other BMPs in conjunction with a filter strip.
b) Filter strips should be located on slopes of 5 percent or less to enhance filtering and infiltration of stormwater runoff. Steeper slopes will generate excessive runoff velocities and cause channelized flow and erosion within the buffer.

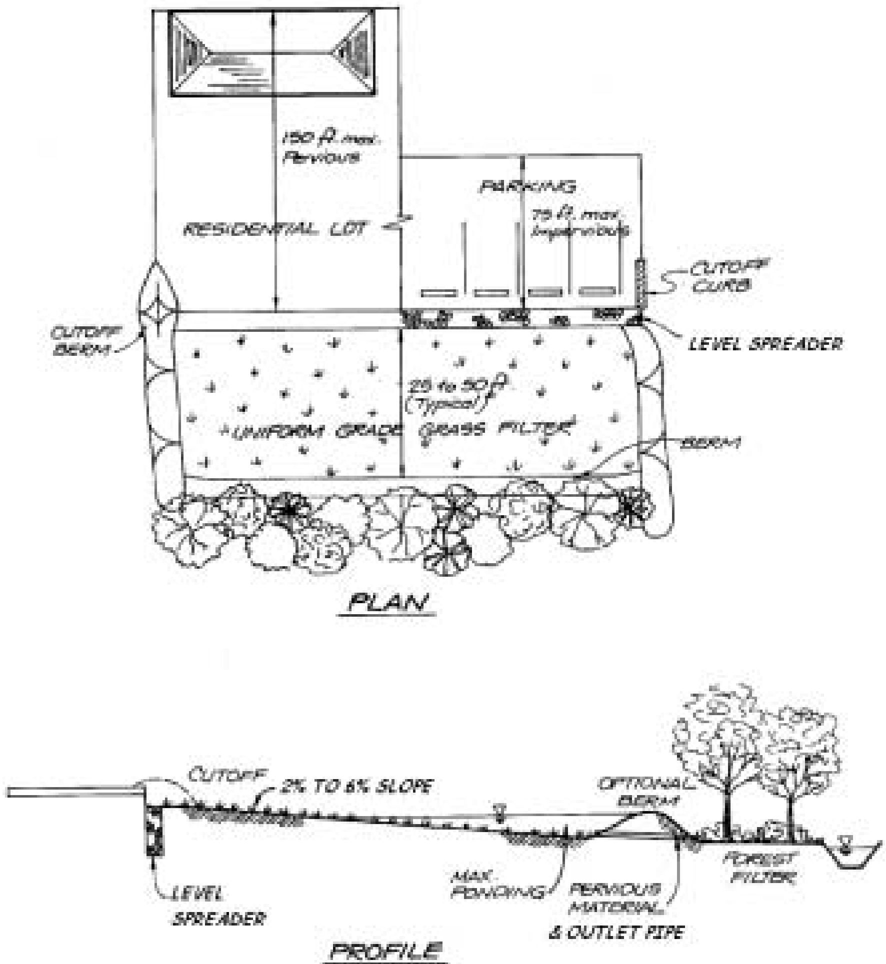


Figure 4.3.4.1-b Drawing of a vegetative filter strip. Source: Adapted from Atlanta Regional Commission, 2001.

c) Filter strips should have topsoil composed of loamy sand, sandy loam, loam, or silt loam. Other soils with higher percentages of finer materials (e.g., silty clay loam or sandy clay) are poorly suited for filter strips due to very slow infiltration rates. They are therefore not permissible and other methods for water quality improvement must be considered.
d) Upland areas regulated as freshwater wetlands such as riverbanks and those areas of land within 50 feet of the edge of any swamp, marsh, pond, or bog *may* be included as part of a required filter strip width. For example, if a project area contains a swamp, marsh, pond, or bog with an adjacent regulated area of 50 feet and it has been determined that a 90 foot filter strip will meet the stormwater performance standards, then the total distance from the outer edge of the filter strip to the swamp, marsh, pond, or bog could be 90 feet. However, the limit of disturbance may be restricted to those portions of the site outside of the regulated area.

Design
a) The filter strip must abut the entire length of the contributing area to ensure that runoff from all portions of the site are treated.

b) Filter strips should be sized to capture the water quality volume behind the berm.
c) The top edge of the filter strip must follow the same elevational contour line to eliminate concentrated flows and "short-circuiting" through the buffer zone.
d) A level spreader device must be utilized along the entire top edge of the filter strip. This device can be a shallow stone-filled trench that evenly distributes the runoff across the entire length of the filter strip. Other devices may be used to achieve an even distribution of runoff, provided the applicant can prove their effectiveness and the design is approved by the permitting agency.
e) The minimum filter strip width shall be 25 feet. The exception will be a 20-foot minimum where filter strips are used as pretreatment for infiltration trenches.
f) Filter strips, or areas proposed as such, must be protected by proper soil erosion and sediment control techniques (e.g., hay bales and silt fences) during all phases of construction. These measures must be properly maintained until final site stabilization and subsequent removal of all trapped sediments has occurred.

Maintenance
a) Filter strips should be inspected at least quarterly during the first year of operation and semiannually thereafter. Evidence of erosion and concentrated flows within the buffer must be corrected immediately. Eroded spots must be reseeded and mulched to enhance a vigorous growth and prevent future erosion problems.
b) Procedures for soil preparation and seeding should be done in accordance with the most recent version of the Permanent Vegetative Cover section in chapter 4 of the *RI Soil Erosion and Sediment Control Handbook.*
c) The bulk of accumulated sediments will be trapped at the top of the filter strip. These deposited sediments should be removed manually at least once per year or when accumulating sediments cause a change in the grade elevation. Reseeding may be necessary to repair areas damaged during the sediment removal process.
d) Grass filter strips should be mowed only once per year, leaving vegetation a minimum of 4 inches in height. Mowing operations are to be conducted during the growing season, but preferably after mid August. This management technique maintains a tall vigorous growth and protects the young of ground nesting animals.

4.3.4.2 Natural and Vegetated Drainage Ways

Structural drainage systems and storm sewers are designed to be hydraulically efficient for removing stormwater from a site. However, in doing so these systems tend to increase peak runoff discharges, flow velocities and the delivery of pollutants to downstream waters. An alternative is the use of natural drainage ways such as grass natural drainage systems (see figures 4.3.4.1-a and -b).

Figure 4.3.4.1-a and b Vegetated drainage ways. Source: Adapted from Atlanta Regional Commission, 2001.

The use of natural open channels allows for more storage of stormwater flows on-site, lower stormwater peak flows, a reduction in erosive runoff velocities, infiltration of a portion of the runoff volume, and the capture and treatment of stormwater pollutants.

Advantages

- Reduces or eliminates the cost of constructing storm sewers or other conveyances, and may reduce the need for land disturbance and grading.
- Increases travel times and lower peak discharges.
- Can be combined with buffer systems to enhance stormwater filtration and infiltration.

Use

a) Use vegetated open channels in the street right-of-way to convey and treat stormwater runoff from roadways, particularly for low-density development and residential subdivisions where density, topography, soils, slope, and safety issues permit.
b) Use vegetated open channels in place of curb and gutter to convey and treat stormwater runoff.
c) Design drainage systems and open channels to:

i. Increase surface roughness to retard velocity.
ii. Maximize sheet flow conditions.
iii. Include wide and flat channels to reduce velocity of flow.
iv. Increase channel flow path to increase time of concentration and travel time.

Standards

Additional design guidance for the construction of natural drainage systems can be found in chapter 6 under "Grassed Waterways" of the most recent edition of the *Rhode Island Soil Erosion and Sediment Control Handbook.*

Site suitability

a) Runoff velocity within the drainage way should be less than *5* feet per second to reduce the potential for gullying and erosion within the natural drainage system.
b) The soils on which grassed natural drainage systems are proposed should have an infiltration rate of at least 0.3 inches per hour.
c) Natural drainage ways should not be closer than 100 feet to any public or private well to prevent the potential for drinking water contamination.
d) The minimum separation distance between natural drainage systems and any component of an individual sewage disposal system should be 50 feet.
e) The bottom of the natural drainage system should have slopes of no more than 4% to prevent excessive velocities and erosion within the natural drainage system (see Figure 4.3.4.1-c). Recommended slope is 1% to 2%.
f) Provide 2 feet of separation to groundwater where contamination may be of issue (e.g., above GAA and GA aquifers).

Design

a) Natural drainage systems should be designed to handle the proposed peak discharge rates from the development based on the 25-yr or 100-yr storm events.
b) Natural drainage systems should be designed using Manning's formula as follows:

Equation 4.3.4.1(a)

$$V = \frac{1.49\, r^{2/3}\, s^{1/2}}{n}$$

Where:

V = flow rate in feet per second
r = hydraulic radius in feet, which can be calculated cross-sectional area over wetted surface.
s = slope
n = roughness coefficient

c) Side slopes of the natural drainage system should be 3:1 (horizontal:vertical) or flatter.
d) The overall slope along the length of the natural drainage system should not exceed 5 percent.
e) Outlet protection measures must be used at any discharge points from the natural drainage system. Stone riprap is one of the more popular methods used to reduce potential erosion at discharge outlets. The design and diameter of the riprap must be appropriate for the expected discharge energy to prevent dislodging of installed riprap.

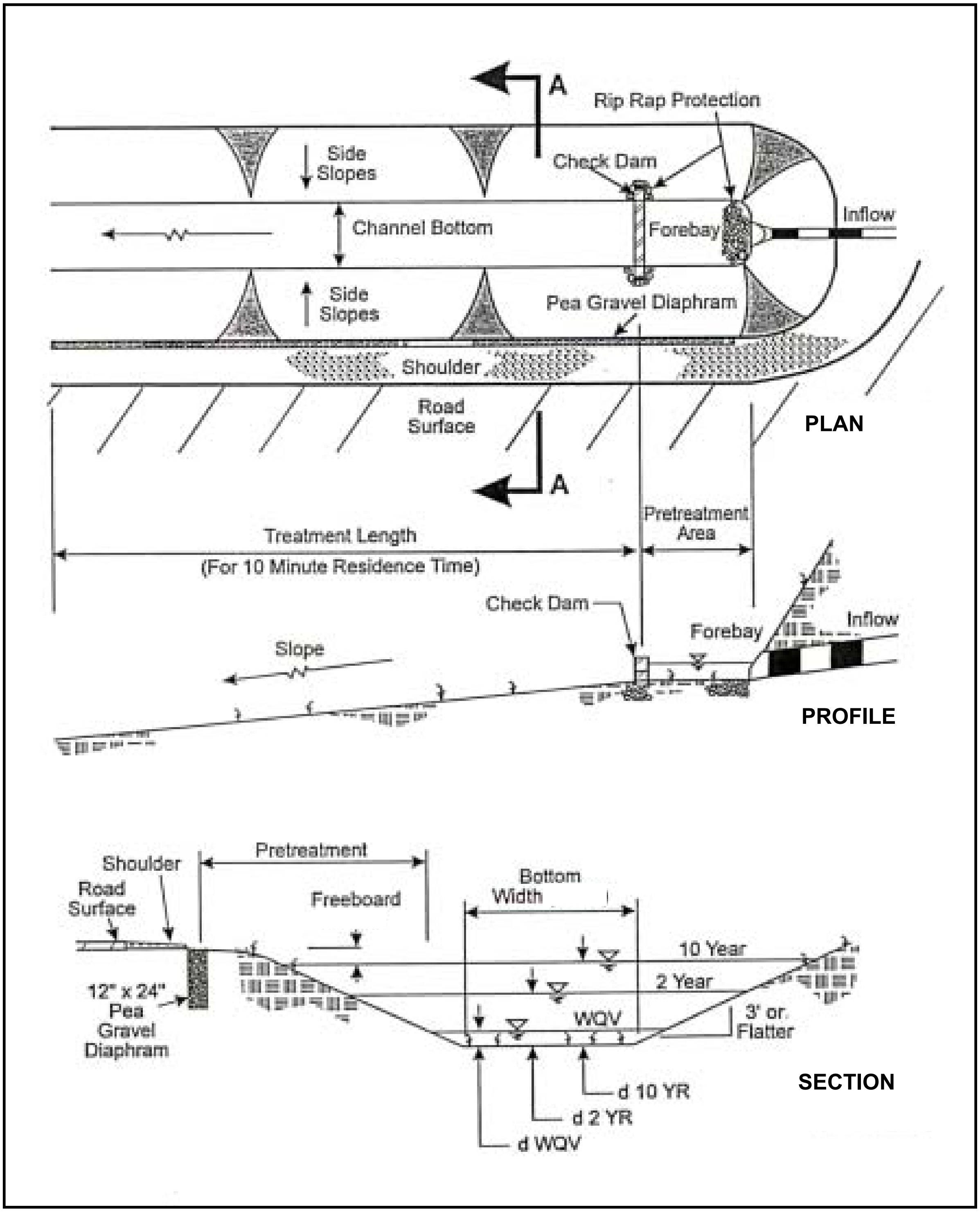


Figure 4.3.4.1-c Features of well-designed natural or vegetated drainage way. Source: Adapted from Connecticut, 2004.

f) The addition of check-dams to the natural drainage system (see Figure 4.3.4.1-c) is encouraged to promote better efficiency in controlling peak discharge rates and improving water quality. The maximum allowable check-dam depth is determined using the following formula:

Equation 4.3.4.1(b)

$$d_{max} = 24f$$

Where:

d_{max} = Maximum depth
24 = maximum allowable ponding time in hours
f = final infiltration rate at the design bottom of the natural drainage system in inches per hour

g) The maximum permissible velocity should be consistent with the grassed waterway design criteria contained in the most recent edition of the *Rhode Island Soil Erosion and Sediment Control Handbook*.
h) The natural drainage system must have a dense cover of water tolerant and erosion resistant grass established immediately following the construction phase. Reed Canary grass (Phalaris arundinacep) is ideal for wet conditions while seed mixtures containing fescues are more tolerant of drier conditions. Additionally, the guidelines for soil preparation and seeding found in the Permanent Vegetative Cover Section of the *Rhode Island Soil Erosion and Sediment Control Handbook* are recommended for guidance.

Maintenance

a) Natural drainage systems should be mowed at least once per growing season to prevent establishment of woody growth and other undesirable plants that inhibit proper performance. Grass vegetation should not be cut shorter than 4 inches. It is important not to engage in excessive mowing operations, as this keeps the grass too short and decreases the efficiency of the vegetation to reduce runoff borne sediments and velocities.
b) Bare spots and eroded areas within the natural drainage system must be reseeded immediately following observations to prevent subsequent failure of the system.
c) Natural drainage systems should be inspected on a semi-annual basis. All trash and other litter must be removed during inspections.
d) Sediments should be removed at least once per year or more frequently if sediments are over topping check-dams. Accumulated sediments must be removed manually to prevent damage to the natural drainage system.
e) Reseeding may be necessary after sediment removal operations, especially if excessive damage is done to vegetation.

4.3.4.2 Green Roofs and Facades

Figure 4.3.4.2-a Chicago City Hall green roof. Source: Photo (c) 2004 Roofscapes, Inc. Used by permission; all rights reserved.

Rooftop runoff management structures are modifications to conventional building design that retard runoff originating from roofs. The modifications include:

- Vegetated roof covers,
- Roof gardens,
- Vegetated building facades, and
- Roof ponding areas.

Roofs are significant sources of concentrated runoff from developed sites. If runoff is controlled at the source, the size of other BMPs throughout the site can be minimal. Rooftop runoff management practices influence the runoff hydrograph in two ways:

- Intercept rainfall during the early part of a storm.
- Limit the maximum release rate.

In addition to achieving specific storm water runoff management objectives, rooftop runoff management can also be aesthetically and socially beneficial.

Advantages

- Rooftop runoff management techniques can be retrofitted to most conventionally constructed buildings.
- Reduces energy consumption for heating and cooling.
- Conserves space.
- Reduces wear on roofs caused by UV damage, wind, and extremes of temperature. Vegetative roof covers can reduce bare roof temperatures in summer by as much as 40 percent.
- Roof gardens, vegetated roof covers, and vegetated facades add aesthetic value to residential and commercial property that attract songbirds, bees, and butterflies.
- Benefit water quality by reducing the acidity of runoff and trapping airborne particulates.
- May reduce the size of onsite runoff attenuation BMPs.

Use

a) Use vegetative roofs on residential, commercial and light industrial buildings.
b) Vegetative roof systems are most appropriate on roofs with slopes of 12:1 to 4:1. Vegetative roofs should not be installed on roofs with slopes
c) Vegetative roofs may be used on flatter slopes if an underdrain is installed.

Design Variations

- ***Vegetated roof cover***: Vegetated roof covers, also called green roofs and extensive roof gardens, involve blanketing roofs with a veneer of living vegetation. Vegetative roof covers are particularly effective when applied to extensive roofs, such as those that typify commercial and institutional buildings. The filtering effect of vegetated roof covers results in a roof discharge that is free of leaves and roof litter. Therefore, it is recommended where roof runoff will be directed to infiltration devices (see Standards for Infiltration Practices and Dry Wells.)

Because of recent advances in synthetic drainage materials, vegetated covers now are feasible on most conventional flat roofs. An efficient drainage layer is placed between the growth media and the roof surface. This layer rapidly conveys water off of the roof surface and prevents water from "laying" on the roof. In fact, vegetated roof covers can be expected to protect roof materials and prolong their life.

If materials are selected carefully to reduce the weight of the system, vegetated roof covers generally can be created on existing flat roofs without additional structural support. Drainage nets or sheet drains constructed from lightweight synthetic materials can be used as underlayments to carry away water and prevent ponding. The total load of a fully vegetated and saturated roof cover system can be less than the design load computed for gravel ballast on conventional tar roofs.

Although vegetative roof covers are most effective during the growing season, they also are beneficial during the winter months as additional insulation if the vegetative matter from the dead or dormant plants is left in place and intact.

- ***Roof Gardens***: Vegetated roof covers blanket an entire roof area and, although presenting an attractive vista, generally are not intended to accommodate routine traffic by people. Roof gardens, on the other hand, are landscaped environments, which may include planters and potted shrubs and trees. Roof gardens can be tailor-made natural areas, designed for outdoor recreation, and perched above congested city streets. Because of the special requirements for access, structural support, and drainage, roof gardens are found most frequently in new construction.

Roof gardens generally are designed to achieve specific architectural objectives. The load and hydraulic requirements for roof gardens will vary according to the intended use of the space. Intensive roof gardens typically include design elements such as planters filled with topsoil, decorative gravel or stone, and containers for trees and shrubs. Complete designs also may detain runoff ponding in the form of water gardens or storage in gravel beds. A wide range of hydrologic principles may be exploited to achieve storm water management objectives, including runoff peak attenuation and runoff volume control.

- ***Vegetated Building Facades***: Vegetated facades provide many of the same benefits as vegetated roof covers and roof gardens, including the interception of precipitation and the retardation of runoff. However, their effectiveness is limited to small rainfall events.

Vertical facades and walls of houses can be covered with the foliage of self-climbing plants that are rooted in the ground and reach heights in excess of 80 feet. Vines can be evergreen or prolific deciduous flowering plants. As for roof gardens, the designer must be judicial in selecting plant species that will prosper in the constructed environment. Planters and trellises can be installed so that vegetation can be placed strategically.

- ***Roof Ponding***: Roof ponding is applicable where the increased load of impounded water on a roof will not increase the building costs significantly or require extensive reinforcement. Roof ponding generally is not viable for large-area commercial buildings where clear spans are required. Special consideration must be given to ensuring that the roof will remain watertight under a range of adverse weather conditions. Low-cost plastic membranes can be used to construct an impermeable lining for the containment area.

Flat roofs can be converted to ponding areas by restricting the flow to downspouts. Even small ponding depths of 1 or 2 inches can attenuate storm water-runoff peaks effectively for most storms.

Design Considerations

Rooftop measures are primarily runoff peak attenuation measures. The methods for evaluating the peak attenuation properties of these measures are based on approaches used for other runoff peak attenuation BMPs. The emphasis of the design should be promoting rapid roof drainage and minimizing the weight of the system. By using appropriate materials, the total weight of fully saturated vegetated roof covers can readily be maintained below 20 pounds per square foot (psf). Because of the many factors that may influence the design of vegetated roof covers, it is advisable to obtain the services of installers that specialize in this area.

Rainfall retention properties are related to field capacity and wilting point. Appropriate media for this application should be capable of retaining water at the rate of 40 percent by weight, or greater. The media must be uniformly screened and blended to achieve its rainfall retention potential. During the early phases of a storm, the media and root systems of the cover will intercept and retain most of the rainfall, up to the retention capacity. For instance, 3-inch cover with 40 percent retention potential will effectively control the first 1.2 inches of rainfall. Although some water will percolate through the cover during this period, this quantity generally will be negligible compared to the direct runoff rate without the cover in place.

Once the field capacity of the cover is attained, water will drain freely through the media at a rate that is approximately equal to the saturated hydraulic conductivity for the media. Through the selection of the media, the maximum release rate from the roof can be controlled. The media is a mechanism for "buffering" or attenuating the peak runoff rates from roofed areas. Rooftop runoff management measures generally are more effective in controlling storms with magnitudes typical of 2-year return frequency storms or smaller. However, because storms of this size constitute the majority of rainfall events, rooftop runoff measures can be important in planning for comprehensive storm water management. These measures are particularly useful when linked to groundwater recharge BMPs such as infiltration trenches, dry wells, and permeable pavements. By retaining rainfall for evaporation or plant transpiration, some rooftop runoff management measures, such as vegetated roof covers, can also achieve significant reductions in total annual runoff. This attenuation of runoff peaks from larger storms should be taken into account when sizing related runoff peak attenuation at the site.

By using specific information about the hydraulic properties of the cover media, the effect of the roof cover system on the runoff hydrograph can be approximated with numerical modeling techniques. As appropriate, the predicted hydrographs can be added into site-wide runoff models to evaluate the effect of the vegetative roof covers on site runoff. The hydraulic analysis of roof covers will require the services of a professional engineer who is experienced with drainage design.

All vegetated roof covers share certain common design elements:

Impermeable Lining

a) In some instances, the impermeable lining can be the watertight tar surface, which is conventional for flat roof construction. However, where added protection is desired, a layer of plastic or rubber membrane can be installed immediately beneath the drainage net or sheet drain. This liner needs to be designed by a professional engineer to ensure proper function.
b) If membranes are used, their resistance to ultraviolet (UV) radiation, extremes of temperature, and puncture must be known. In most cases, covering the sealing material with a protective layer of gravel or geotextile is advisable.

Drainage

a) The drainage net or sheet drain is a continuous layer that underlies the entire cover system. A variety of lightweight, high-performance drainage products will function well in this environment. The product selected should be capable of conveying the discharge associated with the runoff peak attenuation storm without ponding water on top of the roof cover. When evaluating a drainage layer design, the roof topography should be evaluated to establish where the longest travel distances to a roof gutter, drain, or downspout occur. If flow converges near drains and gutters, the design unit-flow rate should be increased accordingly.

b) Drainage nets or sheet drains with transmissivities of 15 gallons per minute per foot, or larger, are recommended.

c) The drainage layer should be able to convey the design unit flow rate at the roof grade without water ponding on top of the cover media. For larger storms, direct roof runoff is permitted to occur. The design flow rates should be based on the largest runoff peak attenuation design storm considered in the design.

d) To prevent the growth media from penetrating and clogging the drainage layer and to prevent roots from penetrating the roof surface, a geotextile should be installed immediately over the drainage net or sheet drain. Many vendors will bond the geotextile to the upper surface of the drainage material.

e) Effective roof garden designs will ensure that all direct rainfall is cycled through one or more devices before being discharged to downspouts as runoff. For instance, rainfall collected on a raised tile patio can be directed to a media-filled planter where some water is retained in the root zone and some is detained and gradually discharged through an overflow to the downspout.

f) In the case of roof ponding, devices, such as the one shown in Figure 4.3.4.2-b, are easily fabricated. However, some form of emergency overflow also is advisable. Emergency overflow can be as simple as a free overfall through a notch in the roof parapet wall.

g) In roof ponding systems, because the roof is impermeable, the runoff hydrograph is

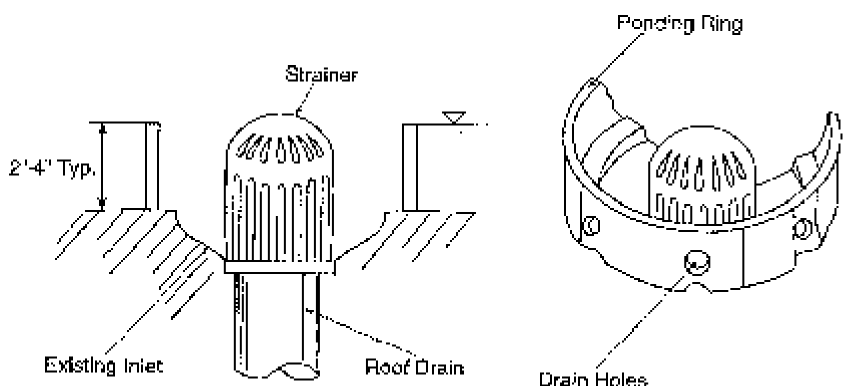


Figure 4.3.4.2-b Roof ponding rings. Source: Adapted from Tourbier, 1974.

simply the rainfall distribution for the design storm multiplied by the area of the roof. The depth to storage relationship can be computed from the topography of the roof. For perfectly flat roofs, the storage volume of a ponding level is equal to the roof area times the ponding level. The depth-discharge relationship in will be unique to the outlet device used. For simple ponding rings, the discharge rate will approximately equal:

$$Q = 3.141\ CD\ (d - H)^{3/2}$$

where: Q = outflow rate

C = discharge coefficient
D = diameter of the ring
d = depth of ponding
H = height of the ring

Roof Loading

The net weight of the fully vegetated roof cover should be compared against the design loads for the roof. Preliminary designs commonly are too light to satisfy the ballast requirements for flat tar roofs. As required, deepening the media can increase the weight of the cover system. In Pennsylvania, the maximum roof design loads must incorporate expected snow accumulation. The design snow load should be added to the weight of the roof system.

Lightweight Growth Media

a) The depth of the growth media should be kept as small as the cover vegetation will allow. Typically, a depth of 3 to 4 inches will be sufficient. Low-density substrate materials with good water-retention capacity should be specified. Examples are mixtures containing crushed pumice and terra cotta. Media that are appropriate for this application will retain 40 to 60 percent water by weight and have bulk dry densities of between 35 and 50 lb/cubic foot. Earth and topsoil are too heavy for most applications.
b) Hydrologic properties are specific to the growth medium. If the supplier does not provide information, prospective media should be laboratory tested to establish porosity, moisture content at field capacity, moisture content at the wilting point (nominally 0.33 bar), and saturated hydraulic conductivity.

Adapted Plants and Grasses

a) A limited number of plants can thrive in the roof environment where periodic rainfall alternates with periods that are hot and dry. Effective plant species must:
   i. Tolerate mildly acidic conditions and poor soil;
   ii. Prefer very-well-drained conditions and full sun;
   iii. Tolerate dry soil;
   iv. Be vigorous colonizers.

   Both annual and perennial plants can be used. Dozens of species have been successfully field-tested. Among these, some species of sedum (Sedum) have been shown to be particularly well adapted. Other candidates include hardy species of sedge (Carex), fescue (Festuca), feather grass (Stipa), and yarrow (Achillea).
b) Vegetative roof covers may include provisions for occasional watering during extended dry periods. Conventional lawn sprinklers work well.
c) The key to developing an effective vegetated facade is selecting plants that are well adapted to the conditions in which they must grow. For instance, depending on the location, plants may encounter shade or full sun. Plants that will provide thick foliage should be selected. Some plants with good climbing and foliage characteristics are ivy (Hedera), honeysuckle (Loniciera), wisteria (Wisteria), Virginia creeper (Part henocissus), trumpet creeper (Campsis), and hardy cultivars of clematis (e.g.,

Cleinatis paniculata). Some of these plants will require a trellis or lattice to firmly support the vines.

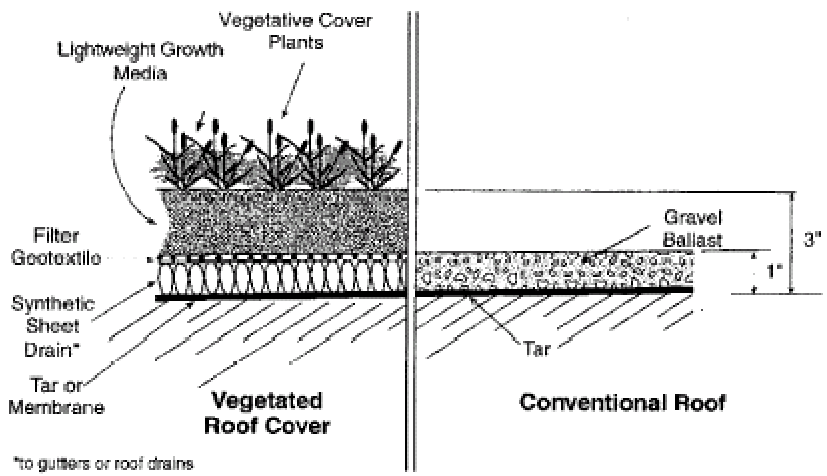
Inspection and Maintenance

a) Plans for water quality swales should identify detailed inspection and maintenance requirements, inspection and maintenance schedules, and those parties responsible for maintenance.
b) All rooftop runoff management measures must be inspected and maintained periodically. Furthermore, the vegetative measures require the same normal care and maintenance that a planted area does. The maintenance includes attending to plant nutritional needs, irrigating as required during dry periods, and occasionally weeding.
c) The cost of maintenance can be significantly reduced by judiciously selecting hardy plants that will out compete weeds.
d) In general, fertilizers must be applied periodically. Fertilizing usually is not a problem on flat or gently sloping roofs where access is unimpeded and fertilizers can be uniformly broadcast.
e) Properly designed vegetated roof covers should not be damaged by treading on the cover system.
f) When retrofitting existing roofs, preserve easy access to gutters, drains, spouts, and other components of the roof drainage system.
g) It is good practice to thoroughly inspect the roof drainage system quarterly. Foreign matter, including leaves and litter, should be removed.

Table 4.3.4.2-1. Typical Maintenance Activities for Rooftop Runoff Structures

Activity	Schedule
• Inspect to ensure vegetative cover is established • Remove foreign matter, leaves, and litter	Quarterly
• Irrigate/Water • Weed	As necessary
• Apply fertilizers to flat or gently sloped roofs	As necessary
• Repair erosion on side slopes with seed or sod	As necessary

Figure 4.3.4.2-c. Example Vegetated Rooftop Cross-section



4.3.4.4 Rain Barrels and Cisterns

Rain barrels and cisterns are rainwater collection and storage devices (see figures 4.3.4.3-a and b). They are generally low-cost, effective, and easily maintainable are applicable to residential, commercial and industrial sites to manage rooftop runoff.

Cisterns are generally larger than rain barrels, with some underground cisterns having the capacity of 10,000 gallons. Water collected in cisterns is typically used for irrigation or in some instances as a potable supply.

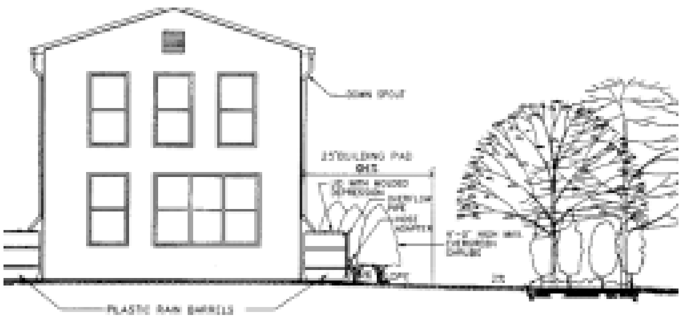


Figure 4.3.4.4-a and b Examples of rain barrels. Source: Prince George's County, Maryland, 2000.

Advantages

- Low cost.
- Applicable to a wide range of sites (e.g., residential, commercial industrial, etc.).
- Provide retention and detention of runoff from roofs.
- Can provide reuse of water for landscape irrigation.

Use

1. Use rain barrels and cisterns in commercial, industrial and domestic settings.
2. Incorporate rain barrels and cisterns when a building is being designed so that they can be blended into the landscape. They can also be retrofitted.
3. Size rain barrels and cisterns based on roof area. The required capacity of a rain barrel is a function of the rooftop surface evaporative water losses and initial abstraction.

   Rain barrel volume can be determined by calculating the roof top water yield for any given rainfall, using Equation 4.3.4.3(a). As a general rule of thumb to utilize in the sizing of rain barrels is that 1 inch of rainfall on a 1000 square foot roof will yield approximately 600 gallons.

   Equation 4.3.4.3(a)
   $V = A^2 \; x \; R \; x \; 0.90 \; x \; 7.5 \; gals/ft^3$

   where:

   V = volume of rain barrel (gallons)
   A^2 = surface area roof (square feet)

R = rainfall (feet)
0.9 = losses to system (no units)
7.5 = conversion factor (gallons per cubic foot)

Example: one 60-gallon barrel would provide runoff storage from a rooftop area of approximately 215 square feet for a 0.5 inch (0.042 ft.) of rainfall.

$60\ gallons = 215\ ft.^2\ x\ 0.042\ ft.\ x\ 0.90\ x\ 7.5\ gallons/ft.^3$

4. If collected water will be used as a drinking source, the system will generally require local authority review and approval.

5. Assure long-term function by establishing maintenance agreements.

Standards

Rain Barrels

For residential applications a typical rain barrel design will include a hole at the top to allow for flow from a downspout, a sealed lid, an overflow pipe and a spigot at or near the bottom of the barrel. The spigot can be left partially open to detain water or closed to fill the barrel. A screen is often included to control mosquitoes and other insects. The water can then be used for lawn and garden watering or other uses such as supplemental domestic water supply. Rain barrels can be connected in a network to provide larger volumes of storage. Larger systems for commercial or industrial use can include pumps and filtration devices.

The following rain barrel technical and operational features should be considered:

1. Screens on gutters and downspouts to remove sediment and particles as the water enters the barrel.
2. A drain cock for emptying the system completely during maintenance.
3. Aesthetic features that are compatible with the lot's landscaping plan.

Cisterns

Individual cisterns can be located beneath each downspout, or the desired storage volume can be provided in one large, common cistern that collects rainwater from several sources. Pre-manufactured residential-use cisterns come in sizes ranging from 100 to 1,400 gallons. Cisterns designed for full time domestic use should be sized based upon a minimum of 30 gallons per day per person when considering all potential domestic water uses. Cisterns should be located for easy maintenance or replacement.

Water Treatment

The water collected with a rain barrel or cistern can also be used for potable (drinking) or other domestic water use if sufficient treatment is provided and the system meets the local plumbing code. Water treatment techniques for rainwater catchment systems include:

1. *Screening*. The use of strainers and leaf screens located in the gutters and downspouts are designed to prevent debris, like leaves, from entering the tank.
2. *Settling.* Sedimentation within the tank is necessary to settle out any potential particulate matter and solids.
3. *Filtering.* The use of filters can include in-line multi cartridge systems, activated charcoal, reverse osmosis, mixed media systems and slow sand filters; all designed to remove potential contaminants either at the pump, tank or tap.
4. *Disinfecting.* The use of boiling/distilling, chemical treatment (chlorine, iodine), ultraviolet light and/or ozonation are all designed to kill microorganisms, usually directly within the tank.

While rainwater catchment systems are largely unregulated in many areas, local regulations may require that plumbing and health codes are be met. Some jurisdictions may require periodic testing of water for fecal coliform bacteria, as is required for any private water system.

Maintenance requirements for rain-fed potable water systems are more extensive than for systems designed to irrigate or simply control stormwater. Typical maintenance consists of keeping gutters and screens clean as well as periodic inspection and replacement of any water treatment components and equipment. The tank also needs thorough cleaning, usually in the summer when its water levels tend to be lower. Backflow prevention devices also require annual inspection. Designers should refer to local authorities for appropriate maintenance protocol and scheduling.

4.3.4.5 Dry Wells

A dry well is a small, excavated pit, backfilled with stone aggregate. Dry wells function like infiltration systems to control roof runoff and are applicable for most types of buildings (see Figure 4.3.4.5-a).

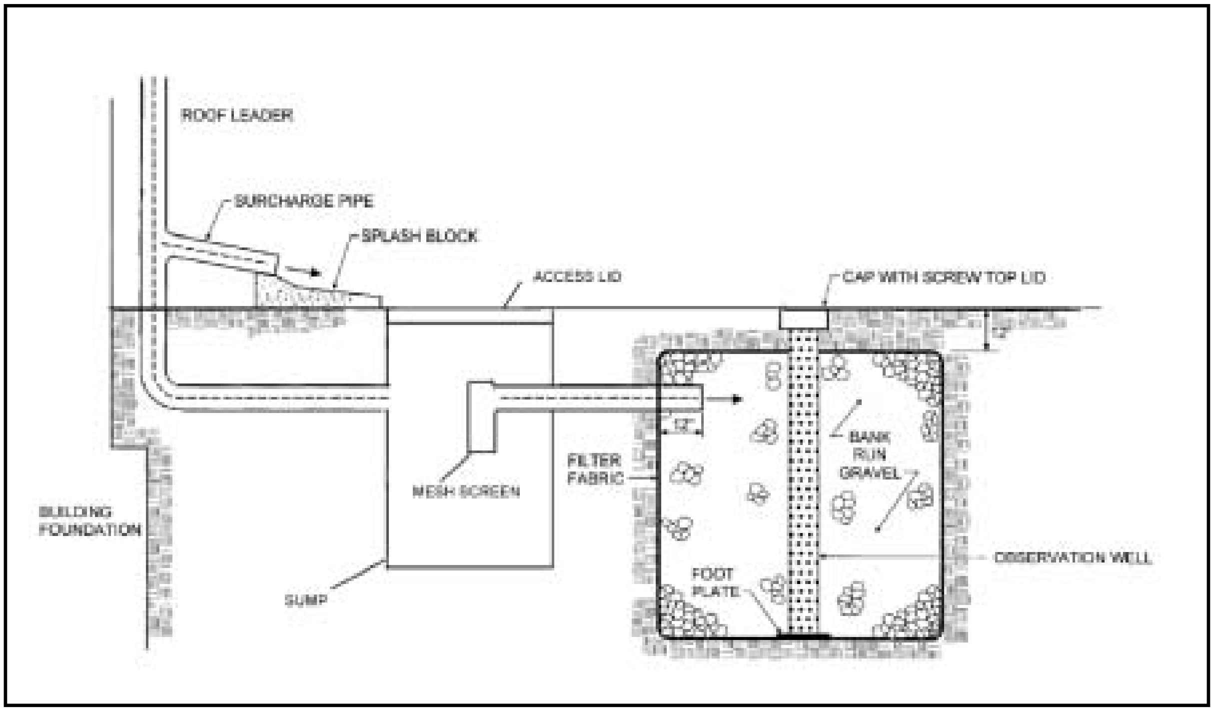


Figure 4.3.4.5-a Schematic of a drywell with optional sump to facilitate cleanout. Source: Adapted from New York, 2001.

Advantages

- Low cost.
- Applicable to a wide range of sites (e.g., residential, commercial industrial, etc.).
- Provides retention of runoff from roofs.
- Recharges groundwater.
- Reduces need for end-of-pipe treatment.

Use

1. Dry wells can be useful for disposing of roof runoff and reducing the overall runoff volume from a variety of building sites.

2. Design dry wells in accordance with the standards below.

3. Infiltration of rooftop runoff from commercial or industrial buildings with pollution control, heating, cooling, or venting equipment may require UIC review and approval.

Standards

Design

1. Dry wells should be designed to accept 1 inch of runoff over the contributing roof area. Dry wells are generally installed at each drainpipe.

2. Dry wells should include an observation well constructed of perforated 4 inch diameter PVC pipe, which extends to the design bottom of the well, and is securely capped to discourage tampering and vandalism. The observation wells can be secured in position by placing a section of rebar through a perforation in the bottom of the pipe, prior to filling the trench with stone aggregate. Consider the inclusion of an optional sump to prevent particulates and debris from entering the leaching chamber and to ease maintenance.

3. Stone aggregate should be 1.5- to 3-inch diameter and should be assumed to occupy 65% of the volume, leaving a 35% void space.

4. Use only clean-washed stone to eliminate particulate matter and reduce the likelihood of clogging the bottom of the well.

5. The void space in the well must be large enough to accept the runoff volume. The volume of the well must equal the volume of runoff divided by the fraction of void space (0.35). As with cisterns and rain barrels, designs should assume a roof runoff rate of 0.9. Dry well volume can be calculated using the following formula:

   Equation 4.3.4.4(a)
   $V = A \text{ x } R \text{ x } C_r \text{ x } C_s = A \text{ x } 0.055$

   Where:
   - V = volume of dry well in cubic feet
   - A = surface area roof in square feet
   - R = 1/12 foot rainfall
   - C_r = coefficient of roof runoff (0.9)
   - C_s = inverse void space fraction (1/0.35)

Maintenance

1. Monitor residual water levels 3 days after rain events on a quarterly basis for the year and annually thereafter. If water is standing in a pipe more than 3 days after a storm event, then clogging has occurred and the dry well requires repair or replacement.

2. All inlets and outlets for these systems must be inspected semi-annually for clogging debris (e.g., leaf litter).

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